ORIENTATION PROGRAMME

ON

GEOGRAPHY CONTENT ENRICHMENT FOR TEACHER EDUCATORS OF AISES AND CTES OF ORISSA

(25th Feb – 1st March, 2004)

A REPORT (MANUAL OF STUDY MATERIAL)

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Preface

Geography remained neglected as a school subject for a long time in the State of Orissa. During mid sixties to mid seventies of twentieth century social sciences were taught in the form of social studies at secondary level in the schools of Orissa. In the Social Study syllabus geography component was much less than expected. Besides a few aspects of human geography, other important domains of geography, particularly Regional Geography and Physical Geography were completely neglected As a result of which, during this phase when educational proliferation in Orissa reached its zenith, geography education remained in the oblivion. Consequently, geography remained confined to a few colleges in Orissa, such as Revenshaw College and G.M College There was no taker of Geography as elective subject at graduate level Facilıty of geography teaching expanded only after mıd-eighties.

Long negligence of geography teaching has resulted in producing a few geography teachers as well as teacher educators in Orissa. In the process, geography is found to be a difficult area to handle in the teacher training programmes Hence this programme was taken up by the NCERT (RIE, Bhubaneswar) in response to the request of the Govt of Orissa This orientation programme aimed at imparting a condensed course in Geography for the purpose of content enrichment of the teacher educators in Orissa The design of the programme was decided in a workshop attended by the experts drawn from Utkal University, Colleges and CTEs of Govt of Orissa. Geography syllabus for class IX and X of the Board of Secondary Education, Orissa and hard spots in the teaching of geography as drawn by the SCERT of Orissa were taken into account while deciding the course content and activities of the programme Training in thıs programme was imparted through lecture-cum-dıscussion, laboratory works and field study Study tour to Chilıka Lake at Satpada was undertaken under the guıdance of Dr. G.K Panda and Mr P.K Mahapatra in order to acquaint the participants with ground realities of physical features related to marine and limnological processes On return from the field vısit the partıcıpants could produce a study tour report to a great satisfaction Thus, we have been able to meet a very ımportant dimension of social study teaching, i e study tour, as recommended by the Natıonal Curriculum Framework for Secondary Education – 2000, Govt of India.

First of all I would like to record my gratitude to Prof M. A. Khader, Principal of RIE, Bhubaneswar for necessary administrative support and encouragements. I am extremely thankful to all the Resource Persons whose active co-operation and deliberation could make this programme a success. They are Prof S N.Tripathy, Dr G.K Panda from Utkal University, Vani Vihar, Bhubaneswar; Dr Dinabandhu Tripathy from Ravenshaw College, Cuttack, Shri B.S.Mallasamanta and Sri Niranjan Dash from S.C.S College, Puri; Shri P.K Mohapatra from the Govt. College, Bhawanipatna and Sri R K.Rath from K S.U B college of Teacher Education, Bhanjanagar I gratefully acknowledge the academic excellence of each one of them Lastly but never the least I extend my sincere thanks to all my friend participants from different CTES of Orissa for their enthusiastic participation in this programme. I am sure, the experience and knowledge they have acquired in this programme shall have wider dissemination effect in improving teaching of geography in the schools of Orissa

P. K. Das
Programme Coordinator

CONTENTS

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Resource Persons

1. **Dr. P.K. Das (Course Coordinator)**	Reader in Geography Regional Institute of Education (NCERT), Bhubaneswar Orissa
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3. **Dr. G.K. Panda**	Reader, Dept of Geography Utkal University Vanivihar Bhubaneswar – 751004
4. **Dr. D. Tripathy**	Reader in Geography Revenshaw College Cuttack
5. **Sri. B.S. Mallasamanta**	Reader & Head, Dept of Geography S C S College Puri
6. **Sri P.K. Mohapatra**	Sr Lecturer in Geography Govt. College Bhawanipatna
7. **Mr. N. Dash**	Sr Lecturer in Geography S C S College Puri
8. **Sri R. K. Rath**	Principal, K S U B College of Teacher Education Bhanjanagar

Lecture Schedule

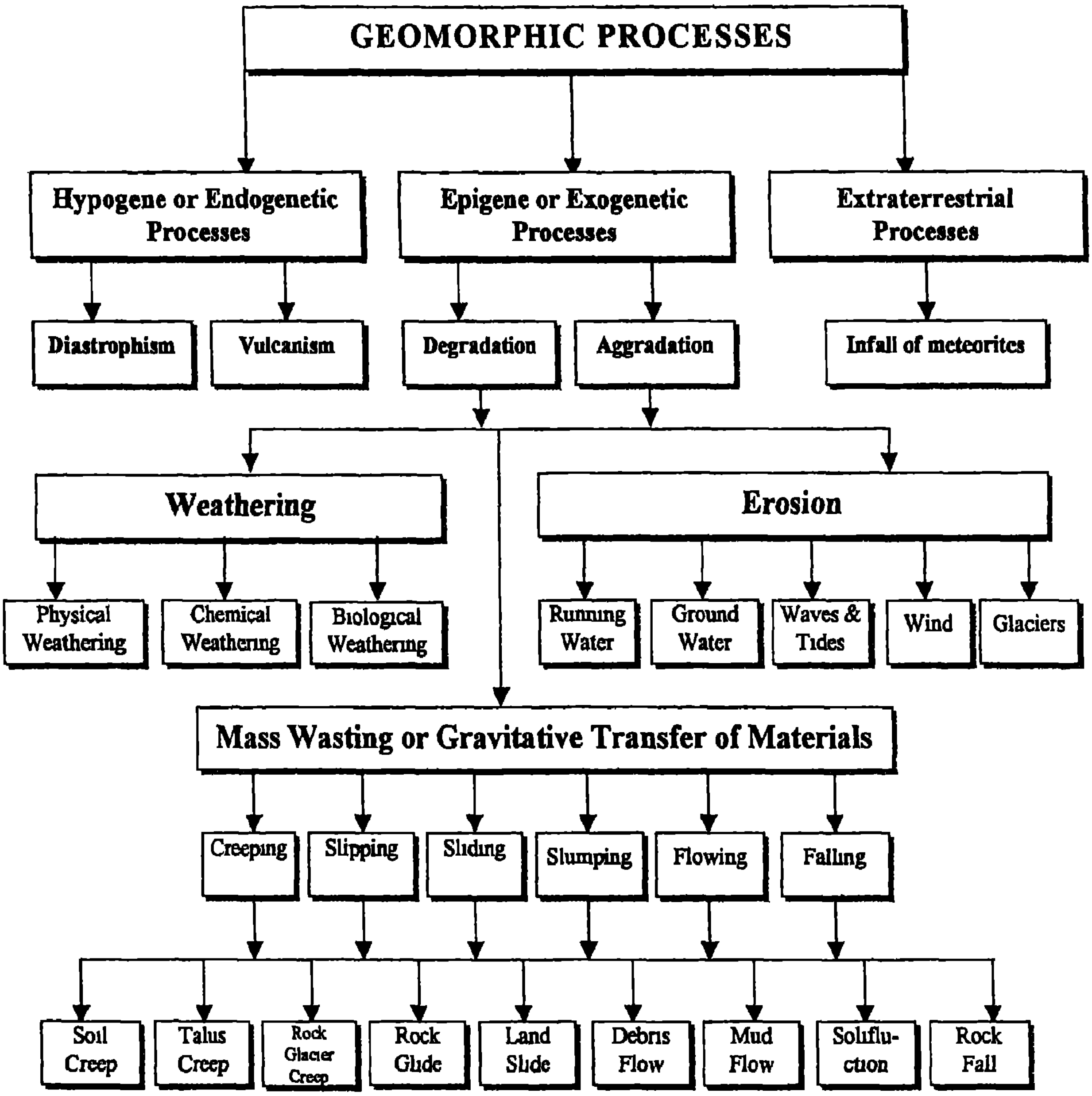
Sl.No.	Topics	Scope
1.	Introduction to Earth	• Origin of the earth (old and modern theories) • Structure & Composition of Earth
2	Longitude, Latitude and Time	• Concept of Longitude and Meridian • Concept of Latitude and Parallels • GMT, Local Time, Standard Time, IST and International Date line
3.	Rotation and Revolution of Earth	• Axis, Day & Night, Twilight • Orbit of the Earth
4	Weathering and Erosion	• Basic Concept of Weathering and Erosion • Different Process of Weathering • Different Processes of Erosion • Cycle of Erosion
5	Action of Erosional Agents	• Work of Running Water and Ground Water • Work of Glaciers • Work of Wind and Wave
6	Earth Movements	• Folds • Faults • Earthquakes and Volcanoes
7	Atmosphere – composition and structure	• Homosphere & Heterosphere • Distribution of Temperature with Height • Different Layers of the Atmosphere and their Features • Ionosphere and Aurora
8	Pressure and Winds	• Forces of Atmospheric Motion • Formation of Pressure Belts • Planetary Winds and Local Winds
9	Hydrological Cycle	• Concept of cycle • Evaporation, Condensation, Condensation Nuclei • Minor Forms of Condensation (Fog, Mist, Dew) • Major Forms of Condensation

Sl.No.	Topics	Scope
10	Precipitation	• Formation of Precipitation • Types of Rainfall • Adiabatic Process • Concept of Stability
11	Cyclones	• Concept of Cyclones and Anticyclones • Origin of Tropical Cyclones • Temperate Cyclones – Polar Front Theory
12	Classification of world climates	• Koppen's Classification Scheme • Natural regions of the World
13	India-Natural Regions	• Macro Regions • Meso Regions
14	Climate of India	• Seasonal Pattern of Air Motion and Rainfall • Monsoon and its Genesis • Concept of Upper Air and Jet stream
15	Climatic classification of India	• India-Its Climatic Divisions
16	Ocean water dynamics	• Waves, Tides and Currents • Waves and their Types • Tides – Formation and Types • Currents-Factors of Formation of Currents • Hypothetical Model of Oceanic Gyre
17	Ocean currents	• Currents in the Atlantic Ocean • Currents in the Pacific Ocean • Currents in the Indian Ocean
	Practical Work	
18	Map and Map Scale	
19	Study of Maps – Toposheet	
20	Contours and Relief Features	
	Field Work	
21.	Study Tour to Chilika Lake at Satapada and Rajahansa	

Landscape is the natural features of an area and the forms superimposed on it by human activities The landscape evolution in relation to geomorphic processes implies the evolution of natural landscape, which has become a major focus of study in physical geography throughout most of the 20th century. Many geomorphic processes are involved in shaping of the landforms and evolution of the landscape While some of the processes are endogenetic i.e. diastrophism and volcanism, most of the processes are exogenetic The evolution of the 1st and 2nd order landform features i.e the continents and ocean basins as well as the mountains and the valleys, plateaus and plains are explained by the diastrophic processes.

The epi-orogenic or eustatic earth movements resulting large scale upliftment and down warping in a regional dimension explains the evolution of the continents and ocean basins The compressional and tensional forces operating in the orogenic belts through isostatic earth movements resulting crumpling, folding, faulting and upliftment of the geosynclinal sediments explain the formation of the mountains and plateaus, plains and valleys The whole gamut of epiorogenic and orogenic processes revealed by the drifting continents of Alfred Wegener of early 20th century, Hess's view of ocean floor spreading of the 1950's supported with the Le Pitchon and Morgan's unifying model of Plate Tectonics of the 1960's through the mechanics of the convection currents explain with the scientific credibility the legacy of the wandering continents with moving crustal plates and the evolutionary idea of the continents and ocean basins, mountains and valleys, plateaus and plains as well as the ridges and island arcs

The sculpturing of the landscape within the 1st and 2nd order landforms are mostly carried out by the external processes induced by a series of agents like streams, glaciers, wind, waves and ground waters guided by the climatic regime and structure of the area But however, the significant aspect of the landscape evolution at the grass root level is carried out by the weathering and hill slope processes which are often imperceptible to human eye. The weathering involves the chemical decay and physical fragmentation of the bedrock While weathering is the first step in the long series of processes that culminate in the formation of debris or detritus, the second step is the downhill movement of the debris by the hill slope processes



This entails the down slope movement of rock debris and soil by mass movement under the influence of gravity and erosion associated with geomorphic agents, mass movements are gravitationally induced displacement of material in the form of processes such as soil creep rock fall, landslide, mudflow and solifluction The rate at which hill slope processes perform work is related in a general way to that climate, topography, and rock type of vegetation cover Most of us would probably agree that the weathering and hill slope processes along with the action of the various geomorphic agents together explain the evolution of the landscape on the surface of the earth

1. Erosion

Erosion is a process of scrapping, scratching, grinding and transportation of the soil and rocks on the earth's surface by running water, moving ice or glacier, waves and currents of the sea, rain water and wind. The existing landscapes on the Earth have mainly been carved and shaped by erosion. Erosion forms soil, finds minerals and adds air and moisture to land, helps in the evolution of lakes, waterfalls, caverns, valleys and natural bridges by erosion. Grand Canyon in the USA is an excellent example of such erosion

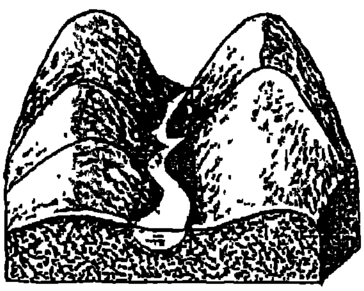
Many geomorphic agents cause erosion. 'V' shaped valleys are result of fluvial erosion whereas 'U'shaped valleys are formed of glacial erosion. River erosion transports soil from one place to another Sand dunes in deserts are formed by wind erosion. Erosion by sea waves carves out caves, notches and sea arcs The processes of erosions are different for different agents. The process of grinding the surface rocks during transportation is called abrasion The wearing action of moving materials is called corrosion. When the blocks of rocks are broken into smaller pieces during transportation by collision are called attrition.

2. Rivers

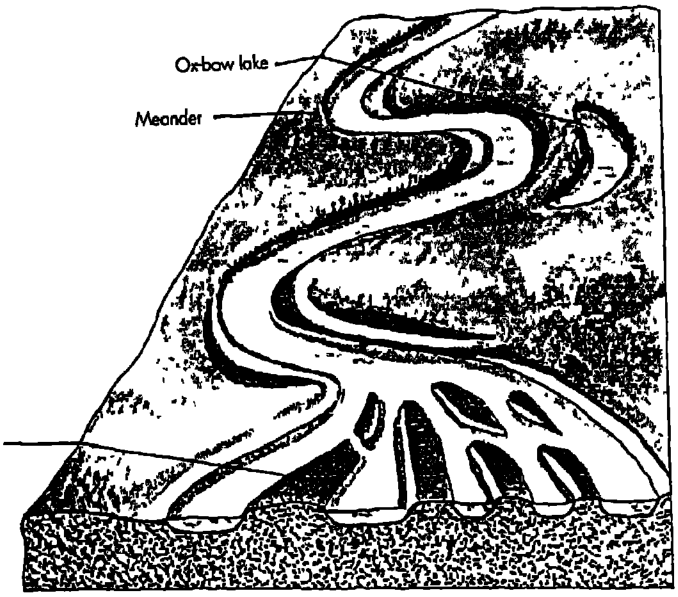
A river is a large stream of water that flows from high land The water in rivers comes from rain, snowmelt, lakes, springs and waterfalls. The river water eventually flows into oceans and lakes There are may kinds of rivers such as the swift flowing rivers, the slow moving rivers, the straight rivers, the meandering rivers, the large and the small rivers. The speed of flow of water in a river depends on the steepness of the river valley The velocity of flow of a river on the mountain slope is higher than that in the plains. The course of a river near its source is narrow but it widens as it moves downstream in to the plain land. The widening of the river valley in the plains is as a result of more of the hydraulic action than that of the structural control

Some rivers owe their origin to melted ice in the mountains while others to the glaciers A river in its youthful stage flows in a mountainous terrain, develops a zigzag course due to structural control and further downwards it develops cascades, gorges, steep valleys and canyons and often water falls In mid course, the river slows down but gathers larger volume of

Youthful stage of a river



Mature stage of a river



Old stage of a river

Caves and caverns are formed by the erosive action of rain or underground water

water from its tributaries and takes many turns In the lower course, the river widens its bed and wends its way leisurely. Here, it forms flood plains, ox-bow lakes, braided streams and deltas Water falling from the height of mountains is called waterfall. A waterfall with a small volume is called a cascade Waterfalls are usually created due to erosion by a river in its upper course When the river passes from more resistant to less resistant rocks, erosion is more rapid in the less resistant formation. Then the river flows down from a height as a waterfall The Niagra Falls and the Great Falls of Yellowstone were formed in this way. Where the drainage area of a river acquires higher level as a result of some natural phenomenon, the river water falls from a height as a waterfall. Sometimes the flow of a river is blocked due to landslide. Consequently, as the volume of water increases, it overflows the blocks of rocks to form a waterfall Waterfalls normally occur in mountainous regions They are also found in regions eroded by ice and glaciers The highest waterfall in the world is the Angel Falls with 979 meter drop in Venezuela Waterfall near Manali in Himachal Pradesh is very beautiful and worth seeing

3. Underground Water

The rainwater and the water from melted ice that reaches under the surface of the earth through pores and cracks are called underground water. Some underground water may originate from the steam rising from molten rock materials deep within the earth Erosive action of water on limestone rocks turns their pores into such big sink holes that even a river draining into them would disappear Springs and artesian wells owe their existence to the flow of underground water Artesian wells are of great economic importance in the mountain-ringed basins in the semi-arid climatic regions of the world There exist more than 18 thousand artesian wells in the world's largest artesian basin in Australia Artesian wells have been sunk in the Terai region of India for irrigation and supply of drinking water

4. Caves And Caverns

A cave is a natural opening in the earth that is big enough for a person or animal to enter Most caves are formed by the erosive action of rainwater or underground water on rocks such as limestone or dolomite The water contains dissolved carbon dioxide which forms dilute carbonic acid This acid dissolves the rock, forming passages and large open spaces Caverns, caves and joint-galleries are the result of this process

The other types of caves are lava caves, ice caves and sea caves Lava caves are found near the base of a volcanic mountain. Ice caves are formed within glaciers. Sea caves are formed in the coastal rocks by the action of sea waves The early man lived in the caves. Even today, some groups of people in Spain and the Philippines live in caves. Kentucky caves in the USA are well known. Stalactites, stalagmites and popcorns are some of the landforms associated with the caves developed by the under ground water.

5. Glaciers

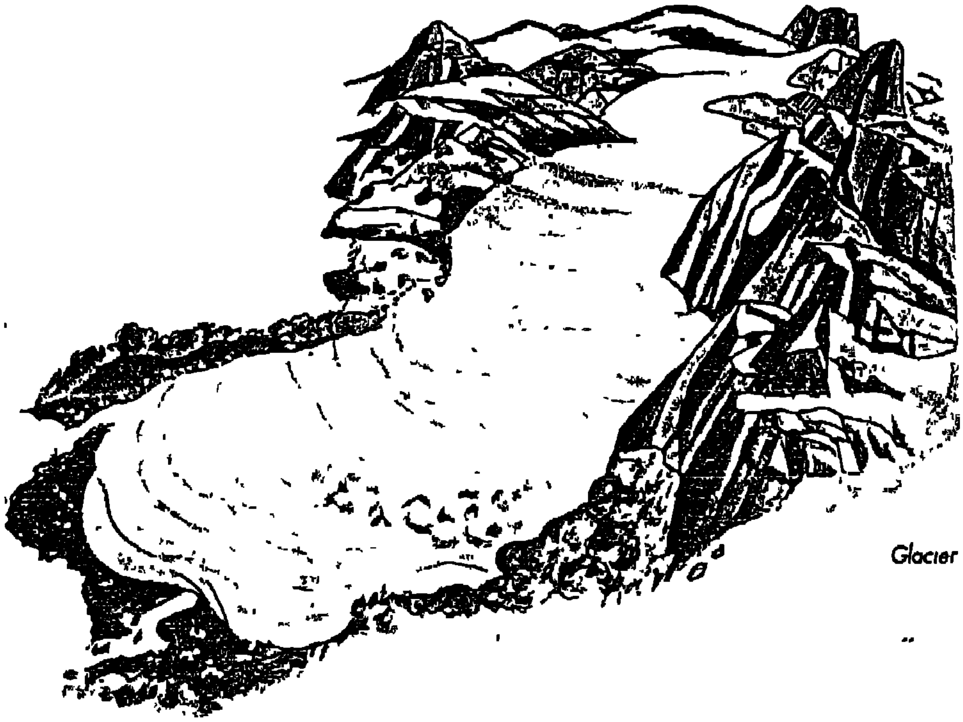
A glacier is a huge mass of snow and ice, which moves slowly down a valley. Glaciers generally occur in polar region and on high mountains above the snow line . The speed of their movement is slow on mountain slopes Glaciers differ in their size and velocity of movement Usually they move about half a meter or one meter a day. But in Greenland, they may move up to 15 metres a day due to their heavier loads (debris) Glaciers cover about 10% of the earth's land surface

In the coastal regions of Greenland and Antarctica large masses of ice broken off from the glaciers float on the sea. They are called icebergs. Normally about one-tenth part of an iceberg is above the sea level and the remaining under the water Some icebergs are up to 90 metres above the sea level while 810 metres hidden under the seawater. Icebergs are of enormous size weighing up to 200 million tons The largest glacier in the world is Lamberts, which are about 515 km long and 70 km wide It lies in the Australia- Antarctica region Other famous glaciers in the world include Zermatt in Switzerland, Loam in Norway, Votion in France and Nishkanevelly in America, Gangotri and Zemu of India Many erosional features like horns, arêtes, cirques, U shaped valleys, fiords and depositional features like moraines, drumlins, eskers and glacial tills are associated with the glacial erosion and deposition

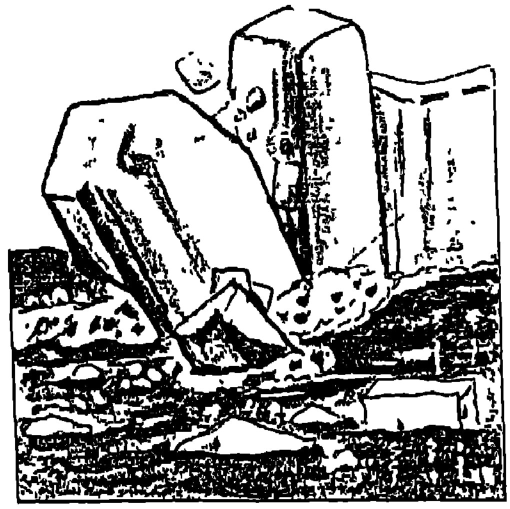
6. Deserts and Wind

A desert is a barren region that has vast expanses of rock and sand It receives very little rainfall In deserts only a few varieties of plants and animals can exit These are those species that require little water They can survive for a long time even without water In most deserts, days are very hot but the nights are cold The deserts are divided into hot deserts and mid-latitude deserts Both these kinds of deserts are found on the western parts of the continents between latitudes 20° and 30°. while the mid-latitude deserts occur in the interiors

GLACIERS



Glacier



Iceberg

of the continents between latitudes 30° and 35° Of the former kind, the best known deserts are the Sahara and the Kalahari in Africa, the south-west American desert, the Great Australian desert, the Chilian desert ın South America and Arab and Thar desert in the south-west Asia The latter type includes the deserts of Turkestan and Gobı

Both in hot as well as the mid-latitude deserts, sand dunes are formed due to the action of strong winds. They may be up to 510 metres high and 900 metres long The highest sand dunes are found in the Sahara desert in Algeria Many erosional and depositional features lıke zeugen, mushroom rocks, pedestral rocks, pediments and bajdas, barchans and playa lakes are associated with the wind erosion process.

ROCKS AND LANDFORMS

1. ROCKS

The rocks are the aggregate of minerals The rocky crust c kinds of rock formations igneous, sedimentary and metamorphic

1.1 Igneous Rocks

Igneous rocks are made up of hot magma The magr volcanic activities forms igneous rocks on coolıng Igneous rock the earth The main igneous rocks are granıte, basalt and volcani formed of the hot liquid lava thrust out from the volcano

1.2 Sedimentary Rocks

Sedimentary rocks are made up of the deposits of grain under the seabed and in fluvıal and aeolıan environments C formed as a result of the forests burıed under swamps in the anc sandstone and clay are the examples of sedimentary rocks. Igne sedimentary rocks constitute 5% of the volume of the earth's cru

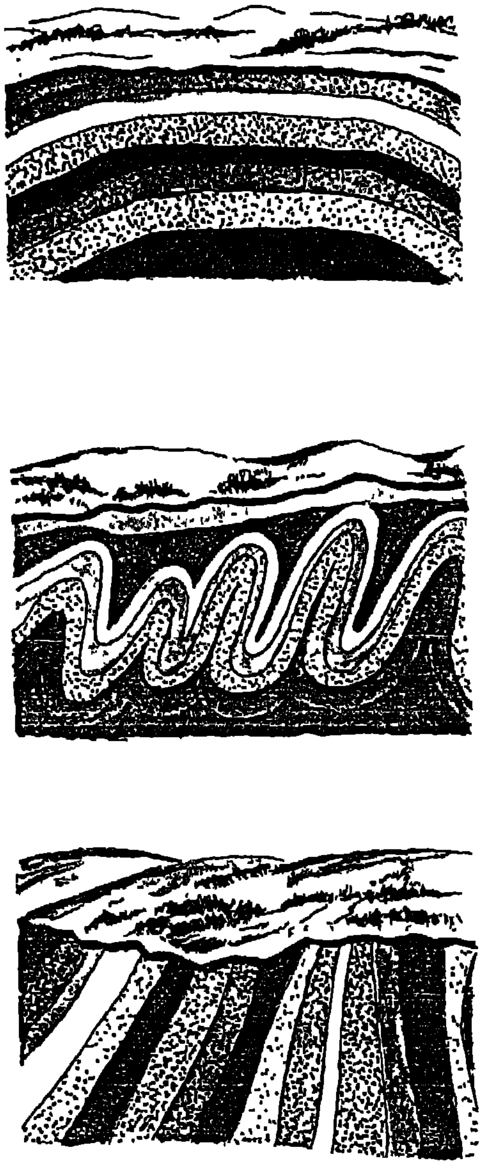
1.3 Metamorphic Rocks

Metamorphic rocks are formed by the actions of hea sedimentary rocks Marble is a metamorphic rock formed a limestone Similarly, clay ıs transformed into slate Precıous ı are found ın several metamorphıc rocks Metamorphic rock foliatıon and occur in massive forms

2. Rocks and Structure: Folds and Faults

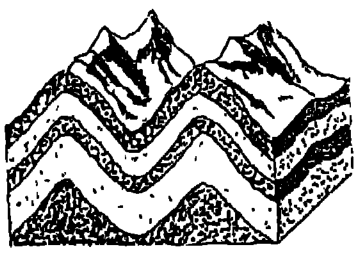
Continuously operating ınternal and external forces ınfl to the earth's crust The ınternal forces cause the slow or secula of years as well as the sudden movements lıke earthqua responsible for foldıng and faulting, whıch give birth to mount

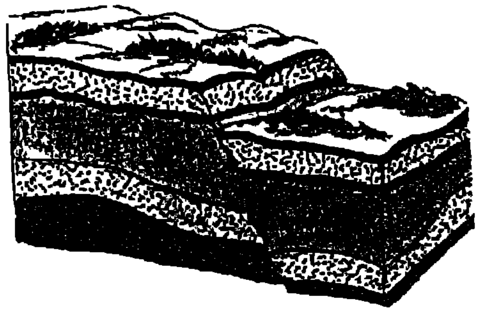
FOLDS AND FAULTS



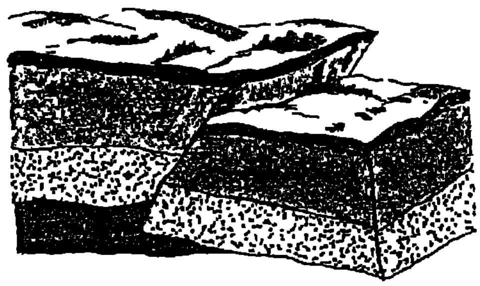
TYes of Folds

Fold mountain

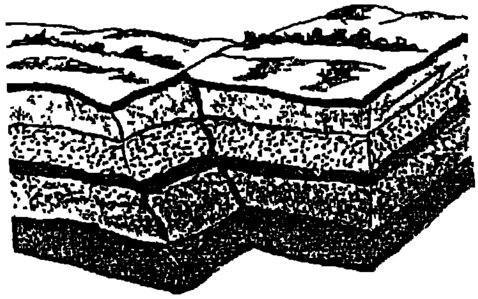




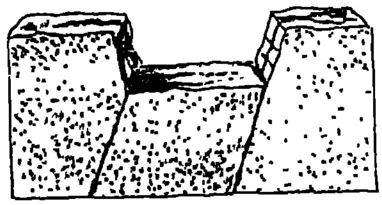
Normal fault



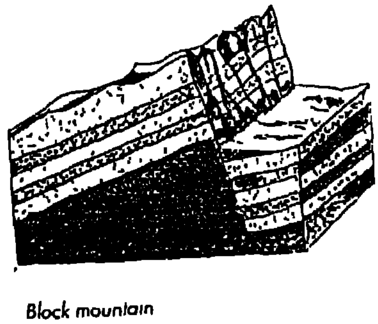
Reversal fault



Tear fault



Rift valley



Block mountain

2.1 Fold

Folding is a process, which produces bends or folds in rock Folding is caused by great compressional (side ways) forces acting on layers of rock in the earth's crust Folds are of various kinds such as symmetrical fold, asymmetrical fold, monoclinal fold, overfold, recumbent fold and nappee. Synclines and anticlines are good examples of symmetrical folds Sedimentary rocks are subjected to folding when compressional forces act upon them.

2.2 Faults

When the rocks within the earth's crust break and move apart due to tension and compression, it is called faulting. Faults can move horizontally or vertically from a few centimeters to many kilometers. Faults are mainly of three kinds - normal faults, reversal faults and tear faults. Faults shape the landscape by their movements. When rocks on one side of fault shift vertically, ridge is formed on the uppermost surface. A block of land that rises between two faults is called a horst A large graben between two faults is called a rift valley.

3. Rocks and Landforms

Different types of rocks use to exhibit in different types of topographic forms. The Sedimentery rocks are mostly found in the form of either uniclinal structures or in the folded forms. The igneous and metamorphic rocks use to occur in massive forms hills and highlands Igneous rocks are found as extrusive forms or intrusive forms depending on the nature of condensation of the magmatic materials above or below the crust The magma condensing above the crust develops volcanic cones, domes and various other smaller forms The lava condensing below the crust form landforms of different shapes and dimensions such as laccoliths, batholiths, lopoliths, sills and dykes Some of these features are concordant i e horizontal to the crust where as many of them are discordant (Vertical to the crust).

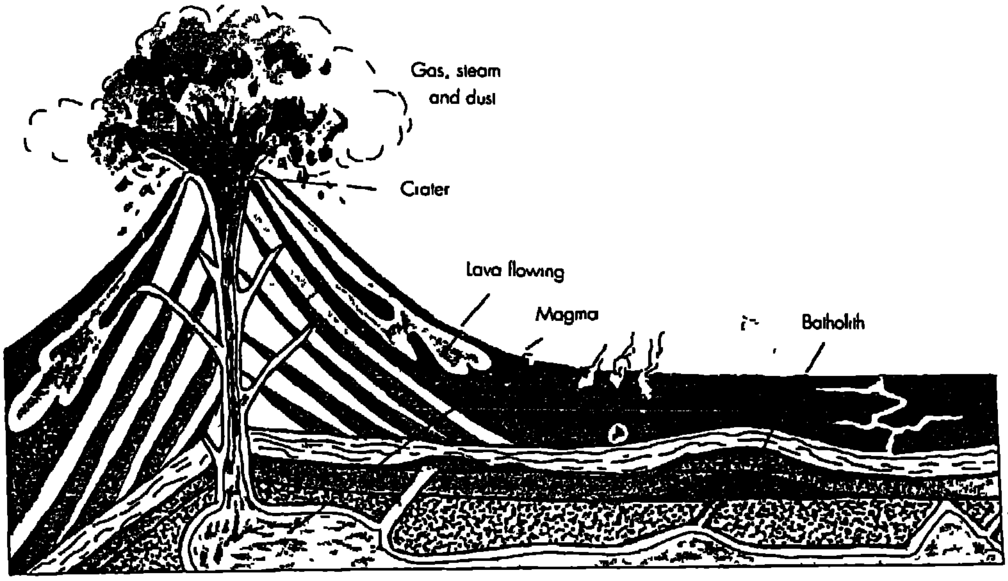
1. Volcano

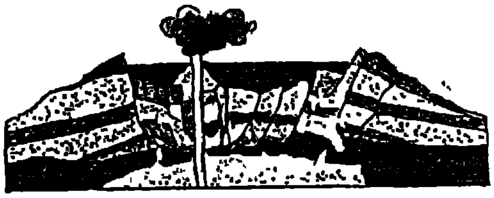
A volcano is a vent or fissure in the earth's crust through which hot solids, gases, smoke and liquids emerge out violently A volcano also refers to the mountain that forms around the hill. The mountains throw up fire, smoke and cinder. When volcanoes erupt, the magma (melted rock) reservoir in the layers of the earth's interior forces itself out through the crust to the surface of the earth. The liquid substance that is forced out as result of volcanic eruption is called lava The lava is a mixture of hot volcanic cinder, pieces of rocks and steam. The number of active volcanoes on the earth is estimated from about 500 to over 800 Most of the volcanoes are funnel or cone shaped and their mouths are called crater. The crater is connected to a pipe-like opening called neck through which magma from the earth's interior is thrown out. By the action of the gases and steam accompanying the magma, the rocks at the top and slopes are blown up to form a hole. Mt Fujiyama, in Japan, is an example of such a volcanic mountain Some volcanoes have dome like tops They are called shield volcanoes Mauna Loa in Hawaii Island is an example of Shield Mountain.

On the basis of the amount of their activity, the volcanoes are classified as (i) active, (ii) dormant and (iii) extinct. An active volcano is always erupting. Hawaii Island's Mauna Loa and Sicily's Mt Etna are examples of active volcanoes. A dormant volcano is temporarily inactive Examples of such volcanoes are Mt Fujiyama in Japan and Mt. Vesuvius in Italy An extinct volcano remains completely inactive for hundreds or thousand of year Mt Kilimanjaro in Africa and Mt. Aconcagua in South America are examples of extinct volcanoes Volcanic eruptions sometimes cause large-scale destructions Pompei and Herculneum were buried under eruption from Visuvius Volcanic eruption in 1883 blew off two-third of Krakatoa island of Indonesia. It was the greatest explosion during the last 3000 years The magnitude of this explosion was equal to that of 1500 megaton of TNT and it was heard as far as 500 kilometers

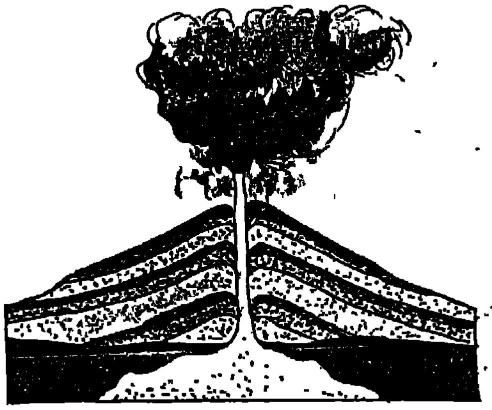
2. Geysers

A geyser is a jet of boiling water and stream issuing from the earth in a few volcanic regions The jet of water may persist from a few moments to an hour or more Beneath the geyser, there is some hot rock out the mouth of the geyser Water reaches the rock through this fissure where it is heated to about 100^0 Celsius Now the steam pressure inside, forces the hot

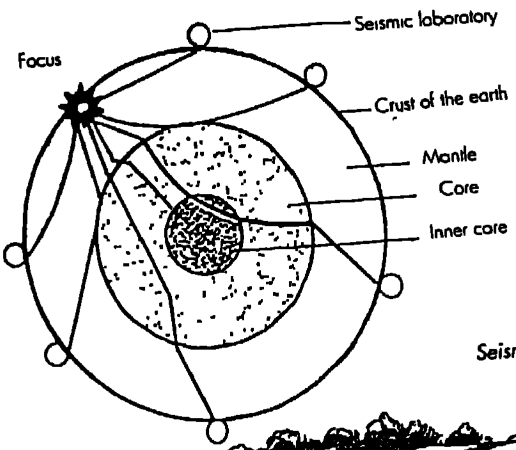


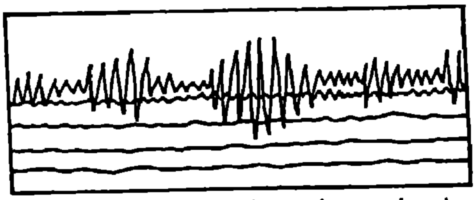


Crater lakes are the craters of extinct volcanoes filled with water



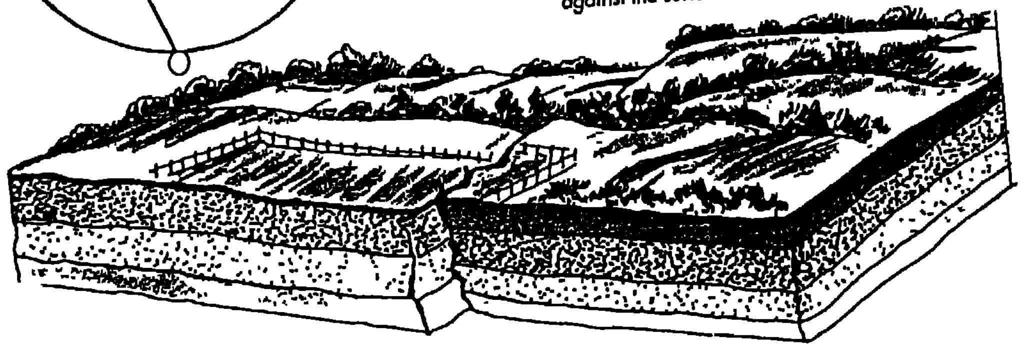
Crater is formed after a volcanic eruption





This is how the seismograph records an earthquake

Seismic waves, like echoes, are reflected back when they strike against the surface of the earth's core



water to come out to the surface of the earth The Flow of hot water continues till such time, as cold water does not return to the fissure. The cold water is again converted into steam and as the pressure rises, the hot water is thrown out The jet of hot water may rise in the air to a height of 100 meters or more. In some cases it rises to only 1 or 1.5 metres. Geysers are known to exist only in Iceland, New Zealand and Yellowstone National Park in the USA Of these three, Yellowstone has by far the most impressive display of geysers

3. Earthquakes

Earthquake produces tremors or vibratory shocks in the earth Sometimes the tremors are so weak that people cannot feel them But at times they are so violent that long cracks are formed in the earth's crust, buildings collapse, monuments topple, and hundreds and thousands of people perish. Such sudden tremors and shocks felt in the earth's crust are called earthquake

There are many reasons behind earthquakes According to seismologist, the outer layer of the earth is made up of many thick plates All these plates are in slow, continual motion with respect to each other Currents within the hot, molten interior of the earth, produced by thermal convection and the earth's rotation, are thought to underlie plate movement In some areas the plates are being driven apart and new molten material is forced upward between plates In other region, the plates slide past each other In a third kind of situation, plates push directly into each other, causing one plate to slide beneath the other The difference in motion between plates causes rocks to fracture along cracks, creating earthquakes

A few local earthquakes are often volcanic in origin Movements of underground molten magma straining and fracturing adjoining surface rocks produce these earthquakes In many places man has felt tremors as a result of deep digging The areas prone to earthquakes are known as seismic belts. Assam in India is one of the World's most earthquake-prone areas The instrument used for seismograph Richter scale is used for recording the intensity of earthquakes

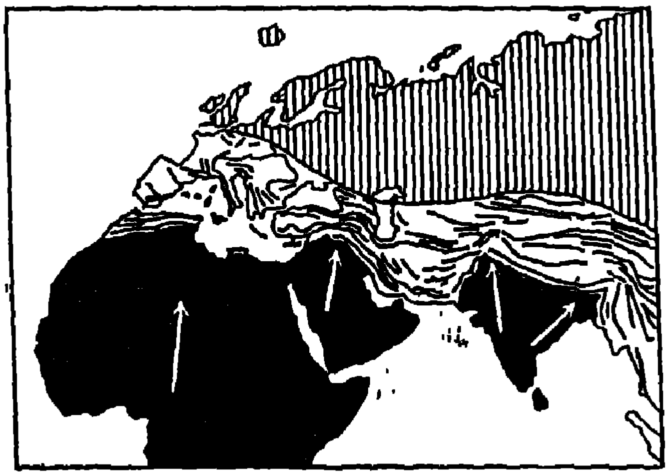
The intensity of the earthquakes is measured through the Richer's scale and Barograph is the instrument used to record the earthquakes

PROCESSES OF MOUNTAIN BUILDING

G. K. Panda

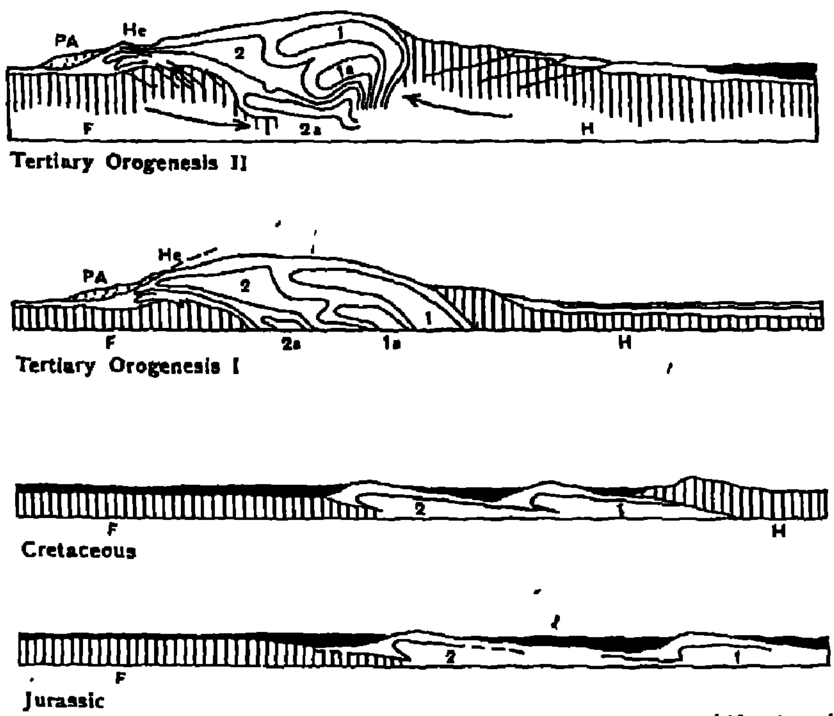
Most of the mountains have been formed due to major changes that have taken place in the earth's crust over the ages They are classified in four categories on the basis of the process of their formation The four categories are; fold mountains Block Mountains, residual mountains and volcanic mountains. Fold Mountains are made up of many layers or rocks They are formed due to violent contractions and pressure inside the earth Because of this, the rocks turn wavy and overlap each other and their layers get folded to rise above the earth's surface to form mountains The Himalayas, the Andes, the Rockies and the Alps came into existence as a result of folding process

Mountains formed by vertical faults are called Block Mountains Great blocks of rock are uplifted above the surrounding terrain because of vertical movements along faults The mountains rise as great tilted blocks The Vosges in France and Black Forests in Germany are the examples of Block Mountains. Residual mountains are formed due to denudation and erosion by which high plateaus are gradually shaped not peaks and ridges. Natural agents such as wind, water, sow, etc cause denudation and erosion. The Catskill range in the southern New York state is an example of residual mountains Volcanic mountains are formed due to accumulation and solidification of lava, ash and debris erupted from the earth's interior. They are basically cone shaped with a crater at the top The Fujiyama in Japan is an example of volcanic mountains. The young fold mountains are formed as a result of folding of the geo-synclinal sediments in the four distinct phases of lithogenesis, cryptogenesis, orogenesis and glyptogenesis.



[*After Argand*

FIG. 31.—The Origin of the Tertiary Mountains of the Old World.



[*After Argand*.

FIG 32 —Stages in the Alpine Orogenesis.

F, Foreland, H, Hinterland, PA, Pre-Alps; He, Helvetian Alps. 1, Dent Blanche nappe, 1a, Monte Rosa nappe. 2, Great St. Bernard nappe; 2a, Simplon nappes

ATMOSPHERE – COMPOSITION AND STRUCTURE

D. Tripathy

1. Introduction

The word "atmosphere" refers to that envelope of air, which encircles the three other spheres of the earth i e., the lithosphere, the hydrosphere and the biosphere Atmosphere is a mixture of different gases along with minute quantity of dust and mineral particles, water vapour, pollen grains and microorganisms. However, the atmosphere is held to the earth by means of its gravitational pull for which the density of the atmosphere is found to be maximum near the surface of the earth and decreases rapidly with increase of height Therefore, it has been estimated that about 50% of the atmosphere mass lies within the height of 5kms. from that of the surface of the earth and the other 50% is distributed within a height of 32kms. The upper limit of the earth's atmosphere merges imperceptibly with outer space having no air at all at a height of 10,000 km from above the surface which may be considered as the outer limit of the atmosphere.

2. Composition

Atmospheric composition simply refers to the mixture of gases, which together define the atmosphere Pure dry air is a colourless, odourless substance consisting largely of Nitrogen (78%) and Oxygen (21%) volume Small quantities several other gases make up the remaining 1% of which Carbon dioxide (0 033%) and Argon (0 93%) are important Other constituent gases are Hydrogen, Helium, Neon, Ozone, Methane, and Krypton etc Besides these gases, the atmosphere contains variable quantities of water vapour, dust particles, pollen grains and microorganisms Of many constituents, the role of water vapour, dust particles carbon dioxide and ozone are considered to be most important from the point of weather and climatic conditions of the earth

Water vapour on condensation leads to precipitation as rain, snow, and hail Dust particles not only contribute towards the heating of the atmosphere by scattering and diffusing insolation but also cause twilight during sunrise and sunset periods Besides, dust particles also act as an hygroscopic nuclear around which water vapour condenses to produce clouds, especially dense haze or smog over industrial cities.

Similarly carbon dioxide absorbs heat and promotes warming of the air by heat waves coming from the earth and sun which ultimately produces a green house effect. The other importance gas i.e., ozone absorbs ultra-violet-radiations from insolation and thus reduces the quantum of insolation and temperature of the earth's surface. However, other inert gases like argon, neon, helium, krypton and xenon have no significance in weather phenomena.

3. Structure

The structure of the atmosphere refers to its layered arrangement, which envelops the earth in a series of concentric shells. However, this structure is being identified on the basis of vertical differences in temperature, movement, composition, degree of electrical charging and radio-wave propagation Both pressure and density decrease with height, Temperature changes unevenly with height i e., (a) slow decrease in temperature up to 15 km (b) a fairly constant temperature up to 80 km On the basis of temperature changes with height, five major layers have been recognized (a) Troposphere, (b) Stratosphere, (c) Mesosphere, (d) Thermosphere and Ionosphere (e) Exosphere and Magnetosphere However, there is no wide variation in chemical composition of the lowermost three layers of the atmosphere i e , up to 80km above the sea level. These three layers (troposphere, stratosphere and mesosphere) are called, as homosphere contrary to which the rest four layers i.e thermosphere, ionosphere, exosphere and magnetosphere are known as heterosphere since there is a great variation in their chemical composition

(i) Troposphere: It happens to be lowermost layer of the atmosphere where most if the weather phenomena take place In this layer, temperature of air decreases at an average rate of 6 4^0 c/km (or 1^0 c/165 meters) of height above sea levels. This is known as the Normal Lapse rate of temperature The average thickness of this layer is about 12 kms Over the poles, greatest thickness at the equator is due to higher insolation near the equator, as a result of which the surface becomes heated and convection currents become very strong and these currents transport heat to great heights But the case is reverse over the poles for which minimum thickness of troposphere is found over the poles Due to the vertical movement of air currents in the troposphere through out the year, this layer remains unstable which leads to upward movement, condensation, formation of clouds and precipitation

The upper limit of the troposphere is known as the Tropopause, which is a transition zone in between troposphere and stratosphere, seasonal changes in the height of the tropopause are known in the middle latitudes and high altitudes. In Northern Hemisphere, its height over 45^0 N latitude is 12 5 kms in January while in July it increase to about 20kms

(ii) Stratosphere : Beyond the tropopause lies the Stratosphere in which temperature increases with increase in height (reaching almost 0^0 at the stratopause). This layer extends up to 50kms However, the rate of increase of temperature is slow up to a height of about 20kms But temperature increases rapidly between 20kms to 50kms as these is a marked concentration of ozone between 20kms to 35kms and most of the harmful ultra-violet radiation from the sun is absorbed by the ozone layer. The gaseous composition of the stratosphere is essentially the same as that at the sea level with two significant exceptions i.e , very little amounts of water vapour and more amount of ozone The upper limit of the stratosphere is the stratopause, which is the transition layer between mesosphere and stratosphere

(iii) Mesosphere : Above the stratopause lies the mesosphere (up to 90kms) where temperature again decreases with height. The composition of mesosphere is almost similar to that of the lower layers except for certain trace constituent such as water vapour and ozone Temperature approaches to about –100 c at the level of mesopause, which is considered to be upper limit of the homosphere and becomes a transitional layer between thermosphere and mesosphere The next layer of the atmosphere just above the mesopause is known as the thermosphere in which temperature again increases with attitude. However, the thermosphere has no well-defined upper limit In this layer, air is being found in rarified from However, the lower most layer of thermosphere specifically in between 80kms to 400kms of attitude is known as the ionosphere that coincides with the lower portion of the heterosphere. This is an electrically charged layer where molecules of Nitrogen and atoms of oxygen are found to be readily ionized because of absorbing high energy short-wavelength solar spectrum In this process each affected molecule or atom loses one or more electrons and becomes a positively charged ion and the elections are set free to travel as electric currents These electrical charged particles or ions reflect back the radio waves to the earth's surface and enable long distance communication by radio waves

Besides radio wave propagation, the auroras, certainly one of nature's most interesting spectacles, take place in the ionosphere The Aurora Borealis (northern lights) and its southern hemisphere counterpart, the Aurora Australis (southern light) appears in a wide variety of

forms. The occurrence of aurora displays is closely correlated in time with solar flare activity and in geographic location with the earth's magnetic poles Solar flares are massive magnetic storms on the sun that emit enormous amounts of energy and great quantities of fast moving atomic particles which energize the atoms of oxygen and molecules of nitrogen of the ionosphere and cause them to emit light i.e., the glow of auroras. The temperature of the thermosphere including the ionosphere increases up to 1650^0c, but due to low density it does not have any impact on the atmosphere

(iv) Exosphere and Magnetosphere: Exosphere and magnetosphere happen to be the outward layers of the hydrosphere extending beyond 10,000 km above the sea level. The density is found to be very low on these layers since these layers consist of the electrically charged particles of helium and hydrogen. The magnetosphere of the earth not only encircles the earth but also goes beyond the atmosphere. The magnetosphere extends as far as from 64,000 km. to 1,30,000 km. The uppermost layer of the magnetosphere is magnetopause. Electrical charged particles are created in this layer due to magnetic effect and the electrons and protons are reacted within the lines of the magnetic field Temperature increases with increase of height within these two layers

D. Tripathy

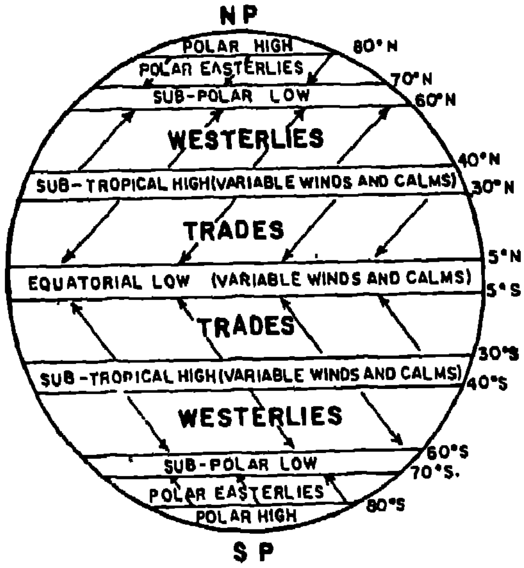
1. Introduction

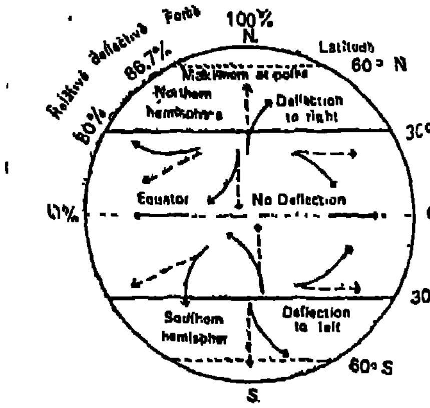
Air in motion is known as wind It is an important element of climate, because it transports water vapour from the oceans to the lands and causes rainfall. The distribution of rainfall on the earth surface is always determined by the main pressure and wind systems of the globe. Winds are always generated by difference in pressure and these differences in pressure are caused by temperature contrasts Besides temperature contrasts, winds are also generated by planetary wind systems caused by dynamic factor of the rotation of the earth Therefore, the atmospheric pressure and winds are more significant as climatic controls and as climatic elements

Because air obeys the law of gases and is compressible, its density is greatest at lower levels where it is compressed under the mass of air above. The pressure exerted by the atmosphere at sea level is about one kg /sq km This is actually the weight of a column of air of one sq.km in cross-section extending from the sea-level up to the outer limits of the atmosphere (i.e , about 10,000 kms of height above the sea-level). The pressure of the atmosphere is balanced by the weight of a column of mercury of the same cross sectional area having 76cms in height in a mercurial barometer. Pressure is used to be expressed in terms of inches and centimeters and is measured in. The common measure is millibar, a unit of force One milibar is a force equal to 1000 dynes per sq.cm , and one dyne is equal to the weight of one milligram Therefore, one millibar is equal to the force of one gram per sq.cm. As air is compressible under pressure or weight, there is a rapid decrease in pressure with increase in height. The lower layers of the atmosphere are the densest owing to the weight of the overlying layers.

2. Causes of Pressure Changes

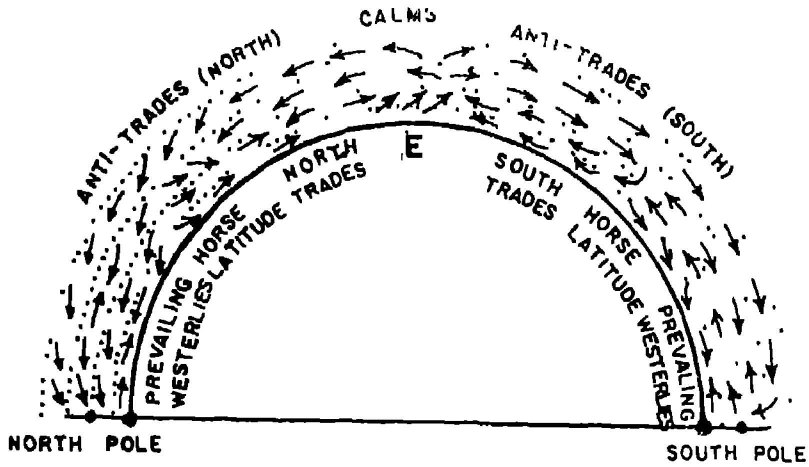
However, there are two types of pressure systems found in the atmosphere (a) High pressure or anticyclone and (b) Low pressure of a cyclone or a depression or a low The oval-shape of high pressure is called a ridge or a wedge and of low pressure is called a trough. There are two causes of the formation of high and low pressure, (i) thermal, and (ii) dynamic



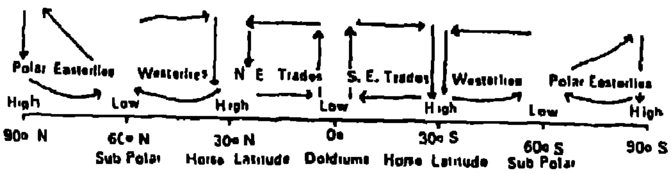


Deflective Force of the Earth's Rotation

. A very diagrammatic representation of pressure and Planetary wind arrangements as they might appear on an earth with a homogeneous surface *(After Finch & Trewartha)*



Air Circulation of the earth E. is the Equator



:.Relation between Pressure and Wind Belts

2.1 Thermal Causes: Pressure of the atmosphere varies owing to differential heating and cooling of the atmosphere When the lower layer of the atmosphere gets heated, it expands, rises and spreads at higher levels. This causes reduction of pressure and formation of low pressure. In contrasts, cooling results in contraction and subsidence of air mass This causes increase in the density of air and consequently high pressure The main process in the formation of thermal high and lows are: (a) conduction and radiation, (b) horizontal advection of warm and cold air masses and (c) latent heat of condensation. Thermal lows are formed during summer in the Central and Southern part of North America and North India, contrary to which are the polar high which occur during winter in the north of Asia and north of North-America

2.2 Dynamic Causes : Dynamics cause operates either through a frictional drag or through centrifugal force originated due to rotation of the earth. Sub-tropical highs and sub-polar lows are examples of dynamically induced pressure systems of the globe.

3. Major Pressure Belts of the World

There are seven permanent pressure belts existing over the surface of the earth, which are also known as planetary pressure belts. The equatorial belt of low or doldrums extends from the equator to about 5^0 to 10^0 North and South. The intensive heating of the atmosphere over this region causes conventional rise of air, which produces low pressure in this region. This belt is known also as belt of equatorial convergence or inter-tropical convergence zone. Similarly, the Polar Regions are centers of high pressures owning to intense cold. These are very small in extent and extend around the North Pole and the South Pole.

The aforesaid three belts i.e. the equatorial low and the polar highs are produced by differential heating of the atmosphere However, there are two sub-tropical high and two sub-polar low-pressure belts due to the dynamic effect of the earth's rotation. Air rising at the equator spreads at high levels and flows from the equator to both north and south poles On account of the rotation of the earth these high altitude winds are deflected towards the right (by coriolis force) or east becoming south-westerly in northern hemisphere and north-westerly in the southern hemisphere These are known as Anti-trade winds as they blow above the trade winds in opposite direction

The subtropical high-pressure belts extend from the tropics (23½° N&S to 35° N&S) The upper air moving towards poles from the equatorial belt cools down and sinks leading to the formation of high pressure over the surface of the earth These belts are also called as the belts of Horse Latitude In southern hemisphere this belt is clearly defined while in the northern hemisphere it is broken into two oceanic centers or Cells, one over the eastern pacific and other

over eastern North Atlantic High pressure at this latitude is the result of convergence of air at higher levels and is accompanied by a general subsidence of the air. From the polar high pressure belts air moves towards equator and meets with surface outflow or air moving from the sub-tropical high pressure belt towards the poles at the middle latitudes i.e. around 60° N and 60° S. Hence, due to the convergence of these two air streams, a low pressure belt is formed which is known as sub-polar low pressure belt. All these permanent pressure belts of the earth have been shown in through diagram, which is of self-explanatory type. These pressure belts are well developed in the southern hemisphere than that of the northern hemisphere because of continuous expansion of ocean in the former as against presence of vast landmasses in the later.

4. Major Wind Belts of the World

Generally air moves from the center of high pressure to centers of low pressure. But wind never moves straight from high pressure to low pressure Rather, there is deflection of wind from its actual path due to rotation of the earth and Ferrel's law explains this nature of deflection It states that the winds are deflected to their right from the source in the northern hemisphere and to their left from the source in the southern hemisphere. The winds are deflected from their actual path as a result of Coriolis force, which is generated by the rotation of the earth This force changes wind direction but not the wind speed. However, the major wind belts of the world are related to the distribution of the major pressure belts of the world and these winds are known as the Planetary or Permanent winds of the globe These are the permanent winds, which blow throughout year from one latitude to the other in response to latitudinal differences in air pressure. So the equatorial low and the sub-polar low pressure belts are regions of converging winds while the high pressure belts are the regions of diverging winds. The resulting flow patterns have prevailing wind with strong easterly or westerly components, which comprise the general circulation

On the basis of existing planetary pressure belts, there are two sets of winds blowing towards the equator from the sub-tropical high pressure belts i.e , one from the north and other from the south and are called a North-East and South-East Trade Winds. These are also called as Tropical Easterlies They cause heavy rainfall to the eastern margin of the continents within the tropics as they blow from the oceans Contrary to this, trade wind becomes an offshore wind on the west cost of the continents. This is one of the reasons for which tropical deserts occur in the western margin of the continents

Similarly, winds blowing from the sub-tropical high pressure belts towards sub-polar low pressure belts are known as Westerly Winds whose direction is mainly south-west in northern hemisphere and north-west in southern hemisphere The pole ward boundary of the westerly fluctuates There are many seasonal and short period fluctuations The westerly wind carry many east moving temperate cyclones with them The westerly wind belt is characterized by cyclones and anticyclones, which result variation in weather from day to day These winds give more rainfall to the western margins of the continents in the temperate belts. In the southern hemisphere, as there is little land and more water beyond 40°S, the westerly winds blow without interruption and with great force i e , more than 75kms/hr and the calms are very rare Therefore, the latitudes 40°S to 50°S, 50°S to 60°s and 60°S to 70°S, on this account are known as Roaring Forties, Furious Fifties and Shrieking Sixties respectively

The last pair of planetary winds are known as polar easterly which blow from polar high pressure belts to sub-polar low pressure belts having the direction from North-East to South-West in the northern hemisphere while South-East to North-West in the southern hemisphere. Polar winds are most irregular among the planetary winds. These winds are generally cold and dry Seasonal migration is found to be very common with respect to the position of the planetary pressure as well as wind belts. In other words the major pressure and wind belts migrate pole-wards during summer while equator ward during winter. This migration of pressure and wind belts is limited to a shift of about 10° of latitude from their normal position. Due to this migration, seasonal contrasts in pressure and winds are found to be maximum in the middle latitudes, where as these are minimum in the equatorial and Polar Regions.

5. Local Winds

Besides the planetary wind systems of the earth, there are other types of winds generally found in small-scale areas produced by locally generated pressure gradient due to local differences in temperature, which ultimately produces differential pressure cells These winds are known as local winds, which not only affect small areas but also are restricted to the lowest levels of the troposphere These winds are generally named locally but vary from place to place On the basis of their occurrence and either on specific time of a day or on specific season of a year, there are two types of local winds· (i) the diurnal local winds and (ii) the seasonal local winds. Land Breeze and Sea Breeze and the Mountain and Valley winds are bright examples of the former while Foehn (in Austria) or Chinook (in Canada), Loo and Norwester (in India) are the examples of the later

P.K. Mohapatra

1. Global Water in Storage

The hydrosphere can be thought of as an enormous storage pool of water in three states, but in greatly differing proportion, depending where and in what state it is stored. Most of the hydrosphere i.e about 97 percent consists of the salt water of the oceans Next in bulk is fresh water stored as ice in the world's ice sheets and mountain glaciers – a little over 2 percent Water in the liquid state is found both on and beneath the earth's surfaces. Water occupying openings in soil and rock is called subsurface water; most of it is held in deep storage as ground water, where it makes up just over 0.6 percent of the hydrosphere Water held in the soil, within spread of plant roots, comprises 0 005 percent Water held in streams, lakes, marshes, and swamps is called surface water; it amounts to about 0.02 percent of the hydrosphere. Most of this surface water is evenly divided between freshwater lakes and salty lakes. An extremely small proportion is temporarily held in streams (rivers) Although the quantity of water held as vapour and cloud particles in the atmosphere is very small – i e 0 001 percent of the hydrosphere-its importance is enormous because this is the avenue of supply of all fresh water

2. The Hydrologic Cycle

Water of oceans, atmosphere, and lands moves in a great series of continuous interchanges of both geographic position and physical state, known as the hydrologic cycle A particular molecule of water might, if we could trace it continuously, travel through any one of a number of possible circuits involving alternately the water vapour state and the liquid of solid state. The hydrologic cycle has three most important stages . evaporation, condensation and precipitation. The atmosphere holds only a very small amount of water although the exchanges with the land and oceans are very considerable The average storage of water vapour in the atmosphere (about 2 5cm, or 1 in) is only sufficient for some 10 days' supply of rainfall over the earth as a whole

The pictorial diagram of the hydrologic cyclic can be quantified for the earth as a whole We can start with the oceans, which comprise the basic reservoir of free water Evaporation from the ocean surfaces triggers the functioning of hydrological cycle This water vapor eventually condenses and returns to the earth in liquid or solid state as precipitation Precipitation is unevenly divided between continents and oceans , The continents receive more

The Hydrologic Cycle

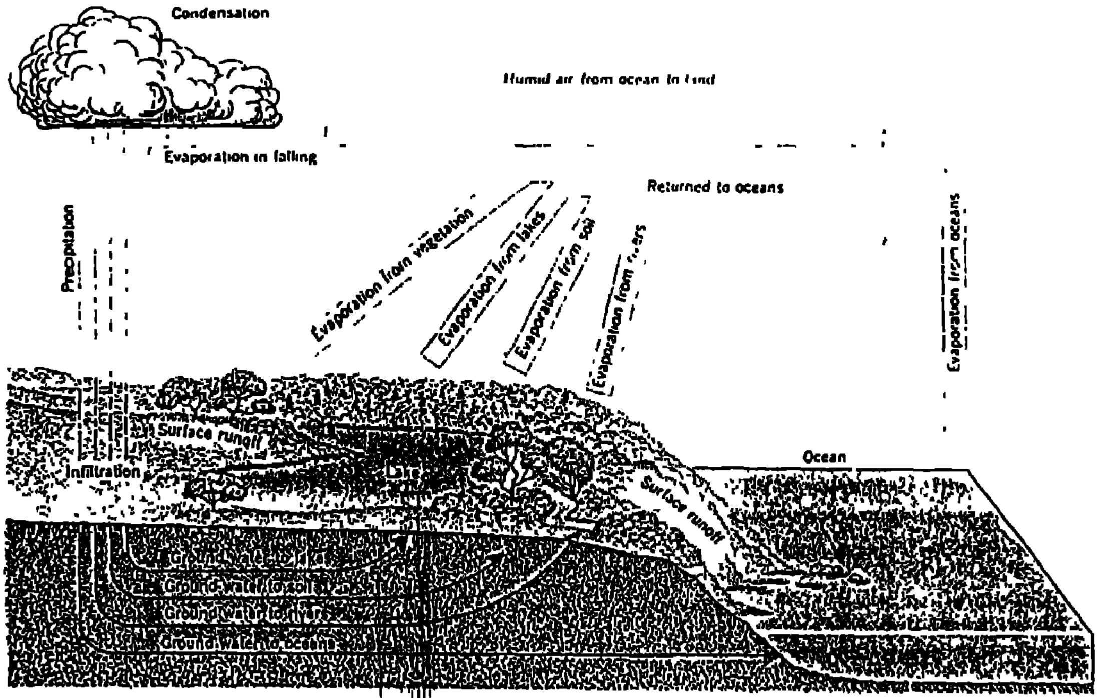
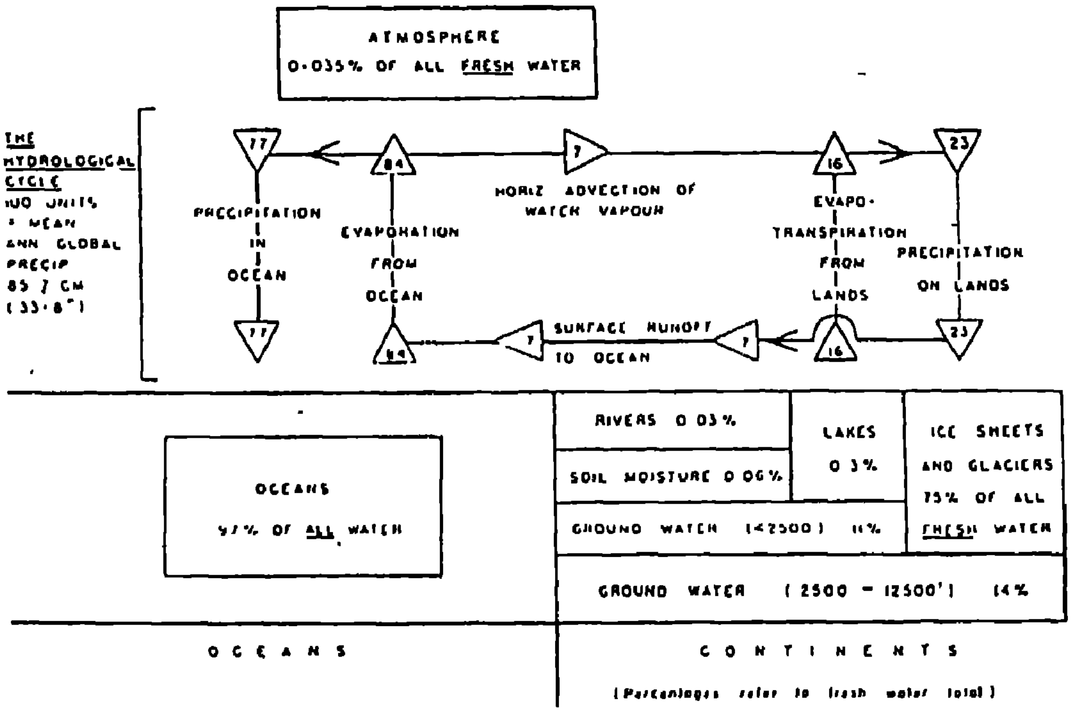


FIGURE 1 · The hydrologic cycle traces the various paths of water from oceans through atmosphere, to lands, and return to oceans.

Figure 2 The hydrological cycle and water storage of the globe. The exchanges in the cycle are referred to 100 units which equal the mean annual global precipitation of 85 7 cm (33.8 in) The percentage storage figures for atmospheric and continental water are percentages of all *fresh* water The saline ocean waters make up 97 per cent of *all* water. The horizontal advection of water vapour indicates the *net* transfer



water as precipitation than they lose by evaporation. This excess quantity flows over or under the ground surface to reach the sea; it is collectively termed runoff. We can state the global water balance as

$$P = E + G + R$$

Where P = precipitation

E=evaporation

G=net gain or loss of water in the system, a storage term

R=runoff (positive sign when running of the continents, negative sign when flowing into the oceans)

All terms are in units of cubic kilometers per year. When applied over the span of a year, and averaged over many years, the storage term G can be considered as zero, because the global system is essentially closed so far as matter is concerned. The quantities of water in storage in the atmosphere, on the lands, and in the oceans will remain about constant from year to year The equation is then simplified to P = E + R

The atmosphere acquires moisture by evaporation from oceans, lakes, rivers and damp soil or from moisture transpired from plants Taken together, these are often referred to as evapo-transpiration and the mechanisms involved will now be discussed in detail

3. Evaporation

Evaporation occurs whenever energy is transported to an evaporating surface if the vapor pressure in the air is below the saturated value (e) The saturation vapor pressure increases with temperature. The change in state from liquid to vapor requires energy to be expanded in overcoming the intermolecular attractions of the water particles This energy is generally provided by the removal of heat from the immediate surroundings causing an apparent heat loss (latent heat) and a consequent drop in temperature. The latent heat of vaporization to evaporate 1 kg of water at 0°C is 2 5 x 10^6 J (or 600 cal g^{-1}) Conversely, condensation releases this heat, and the temperature of an air mass in which condensation is occurring is increased as the water vapour reverts to the liquid state The diurnal range of temperature is often moderated by damp air conditions, when evaporation takes place during the day and condensation at night Viewed another way, evaporation implies an addition of kinetic energy to individual water molecules and, as their velocity increases, so the chance of individual surface molecules escaping into the atmosphere becomes greater As the faster

molecules will generally be the first to escape, so the average energy (and therefore temperature) of those composing the remaining liquid will decrease and the quantities of energy required for their continued release become correspondingly greater In this way evaporation decreases the temperature of the remaining liquid by an amount proportional to the latent heat of vaporization

The rate of evaporation depends on a number of factors The two most important are the difference between the saturation vapor pressure at the water surface and the vapour pressure of the air, and the existence of a continual supply of energy to the surface Wind velocity also affects the evaporation rate because the wind is generally associated with the importance of fresh, unsaturated air, which will absorb the available moisture. Water loss from plant surfaces, chiefly leaves, is a complex process termed transpiration. It occurs when the vapour pressure in the leaf cells is greater than the atmospheric vapour pressure, and is vital as a life function in that it causes a rise of plant nutrients from the soil and cools the leaves

4. Moisture Transport

It is sometimes overlooked that the atmosphere transports moisture horizontally as well as vertically. Moisture must be transported meridionally in order to maintain the required moisture balance at a given latitude (i.e precipitation – evaporation = net horizontal transport of moisture into the air column) A prominent feature is the equator ward transport into low latitudes and the poleward transport in middle latitudes.

At this point it is necessary to stress emphatically the fact that local evaporation is, in general, not the major source of local precipitation. For example, only 6 percent of the annual precipitation of Arizona and 10 percent of that over the Mississippi River basin is of local origin, the remainder being transported into these areas (i e. moisture advection). Even when moisture is available in the atmosphere over a region only a small portion of it is usually precipitated This depends on the efficiency of the condensation and precipitation mechanisms, both microphysical and large-scale, which we shall now consider.

5. Condensation

Condensation, the direct cause of all the various forms of precipitation, occurs under varying conditions which in one way or another are associated with change in one of the linked parameters of air volume, temperature, pressure or humidity Thus, condensation takes place (i) when the temperature of the air is reduced but its volume remains constant and the air is cooled to dew point; (ii) if the volume of the air is increased without the addition of heat; this cooling takes place because of adiabatic expansion (iii) when a joint change of temperature and volume reduces the moisture holding capacity of the air below its existing moisture to the air The key to the understanding of condensation clearly lies in the fine balance that exists between these variables. Whenever the balance between two or more of them is disturbed beyond a certain limit condensation may result.

The most common circumstances favourable to the production of condensation are those producing a drop in air temperature, namely contact cooling, mixing of air masses of different temperatures and dynamic cooling of the atmosphere. Contact cooling is produced, for example, within warm, moist air passing over a cold land surface On a clear winter's night strong radiation will cool the surface very quickly and this surface cooling will gradually extend to the moist lower air, reducing the temperature to a point where condensation occurs in the form of dew, fog or frost, depending on the amount of moisture involved, the thickness of the cooling air layer and the dew-point value

The mixing of the differing layers within a single air mass or of two differing air masses can also produce condensation Vertical mixing of an air layer can have the same effect The addition of moisture into the air near the surface by evaporation occurs when cold air moves out over a warm water surface. Undoubtedly the most effective cause of condensation, however, is the dynamic process of adiabatic cooling

5.1 Condensation Nuclei

It is very important to note than condensation occurs with the utmost difficulty in clean air, moisture must generally find a suitable surface upon which it can condense If pure air is reduced in temperature below its dew point it becomes supersaturated (i.e. relative humidity exceeding 100 percent) To maintain a pure water drop of radius 10^{-7}cm (0 001 μm) requires a relative humidity of 320 percent, and for one of 10^{-5} cm (0.1 μm) radius 101 percent

Usually condensation occurs on a foreign surface, which can be a land or plant surface, as is the case for dew or frost, while in the free air condensation begins around so-called hygroscopic nuclei These are microscopic particles – aerosols – the surfaces of which (like the weather enthusiast's seaweed!) have the property of wettability Aerosols include dust, smoke, salts and chemical compounds. Sea salts, which are particularly hygroscopic, enter the atmosphere principally by the bursting of air bubbles in foam and are a major component of the aerosol load near the surface of the oceans Other large contributions are from fine soil particles and various natural, industrial and domestic combustion products raised by the wind.

5.2 Forms of condensation

5.2.1 Condensation forms due to adiabatic cooling (Ground Forms) Most forms of condensation in the atmosphere result from the air being cooled in some way Condensation near the ground results from contact cooling, advection cooling and radiation cooling A number of weather phenomena result from condensation occurring at ground level

(a)Dew: Dew is the moisture deposited in the form of water droplets on the surface of vegetation and other objects located near the ground level. It forms when nocturnal (night time) terrestrial (long wave) radiation causes heat loss from the Earth's surface, thereby, cooling the lowest layer of the atmosphere below dew point, leading to condensation Dew forms under some favourable conditions, such as calm air, low wind speed (<1 Knot at 2m), high humidity near the surface and a suitable radiating surface Thus, clear skies, which promote rapid nighttime cooling and calm weather associated with light divergent winds, are most favourable to dew formation The ideal conditions occur after a warm day that has followed a period of heavy rainfall when the humidity will be especially high

(b) Frost: When the temperature falls below freezing point, frost forms If the cooling is not too severe, only the ground and the air immediately in contact with it will reach 0°C and this causes ground frost An air frost occurs when the temperature of a whole layer of air near the ground also falls below freezing point

(c) Rime :It is a deposit of white opaque ice crystals formed by the freezing of super cooled water droplets on the surfaces having temperature below 0°C It grows on the windward side of the surface especially, on sharp edges by impaction of the droplets drift past in the wind

(d) Mist forms on wet surfaces, lakes or rivers, where the humidity is high and condensation in evening has led to wisps of mist over the fields and near water, especially in sheltered spots At dawn, next day, mist quickly evaporates

(e) Fog: A mist becomes a fog when the visibility is reduced to below one kilometer Fogs are formed due to different causes and so, there are different types of fogs are produced by cooling

5.2.2 The fogs produced by cooling

(i) Radiation Fog: Radiation fog occurs under conditions of clear night skies, light winds, humid air mass near the ground and dry air above Under these circumstances, the ground cools rapidly since the radiation from the ground is only slightly offset by the radiation downward because of the low total water vapour content of the air column. Once the ground has become sufficiently cooler than the moist air immediately above it, the moist layer absorbs less radiation than it emits and cools Ultimately, it becomes saturated and produced fog. Radiation cooling produces condensation in the air layers immediately above the ground If only a thin layer of moist air is present, dew will form, if a thicker layer is present, radiation fog (and dew) will form. Radiation fog varies in depth from only 3 feet (1m) to about 1,000 feet (300m) If any smoke is present, it may combine with the fog to produce smog

(ii) Advection Fog: Advection fog results from the horizontal motion of the air over a colder a surface, either land or sea When a horizontally moving warm air blows over a cool surface, it cools below its dew point. This occurs most commonly over the oceans where warm air blows over a cold ocean current, leading to fog formation also called Sea fog. Advection fog forms under the conditions of

a) Sharp contrast between air temperatures and temperatures beneath it.

b) High relative humidity of the air and

c) Moderate wind speed.

(iii) Upslope Fog: Upslope fogs form when the air near the ground is cool enough so that it will not rise and it is moist enough so that when it moves upslope it can cool to the dew point As the air starts moving upslope along hillsides or mountain slopes, it undergoes cooling and eventually reaches saturation Any further ascent of the saturated air produces fog called upslope fog When seen from a great distance from the mountain upslope fog may appear like a cloud (which it is)

5.2.3 The Fogs formed by the evaporation

(i) Frontal Fog: Frontal fog is formed by evaporation after it has been raining for hours During that time the falling raindrops evaporate into the air beneath the clouds until the air is moistened to saturation As the raindrop, through the air they evaporate and fill the air with water vapour The warmer raindrops fill the cooler air with more vapour than it can hold

producing fog. This type of fog occurs near fronts when rain from warmer air, just above the front, falls through the colder air near the ground; hence it is called precipitation fog

5.2.4 Condensation forms due to adiabatic cooling

(i) **Clouds:** The most important result of adiabatic cooling is the formation of clouds Clouds are visible aggregates of minute particles of water or ice, or both held in suspension in free air. Clouds like fogs are composed of masses of water droplet but unlike fogs, which are formed just above the ground, clouds form in the air.

Clouds are the result of cooling of air consequent upon upward movement When air ascends it undergoes expansion as atmospheric pressure decreases. Expansion of a body of air entails the increased separation of molecules and so an increase in their potential energy. This energy must be provided in the form of heat but since the rising air mass is only surrounded by more air, it is cut off from any external source The heat, therefore, must be supplied by the rising air mass itself and the temperature falls. The fall in temperature cools the air below dew point and condensation takes place at a particular level above the earth's surface and that forms the cloud. Clouds were given no universally acceptable scientific names until the beginning of the 19th century. Baptist Lamarck was the first to classify clouds, which was upstaged by the English pharmacist and naturalist Luke Howard in 1803. Howard's modified form is the one in use universally, and is used in the international cloud atlas (WMO). Clouds form in three basic patterns (i) Curly or fibrous clouds, known as Cirrus clouds,(ii) Layered or stratified clouds, known as stratus clouds and (iii) Lumpy or heaped clouds, known as cumulus clouds. Clouds are also distinguished by the heights above ground level at which they form. Thus, four categories of clouds can be identified such as (i) High clouds have bases usually more than 6 km. above the ground level, (ii) Middle clouds whose base lie between 2 and 6 km. (iii) Low clouds whose bases lie below 2 km and (iv) Clouds of vertical development Clouds that produce precipitation are known as *nimbo or nimbus*, fractured or broken clouds are known as fracto, and lens-shaped as lenticular, small or himber as humilis, average, medium sized as *mediocre*, swollen or developing as *congestus*, undulating or forming in waves as *undulates*, bearing turrets that resemble battlements as *castellanus*, hooked as *uncinus* and nebulous or fine as *nebulosis*.

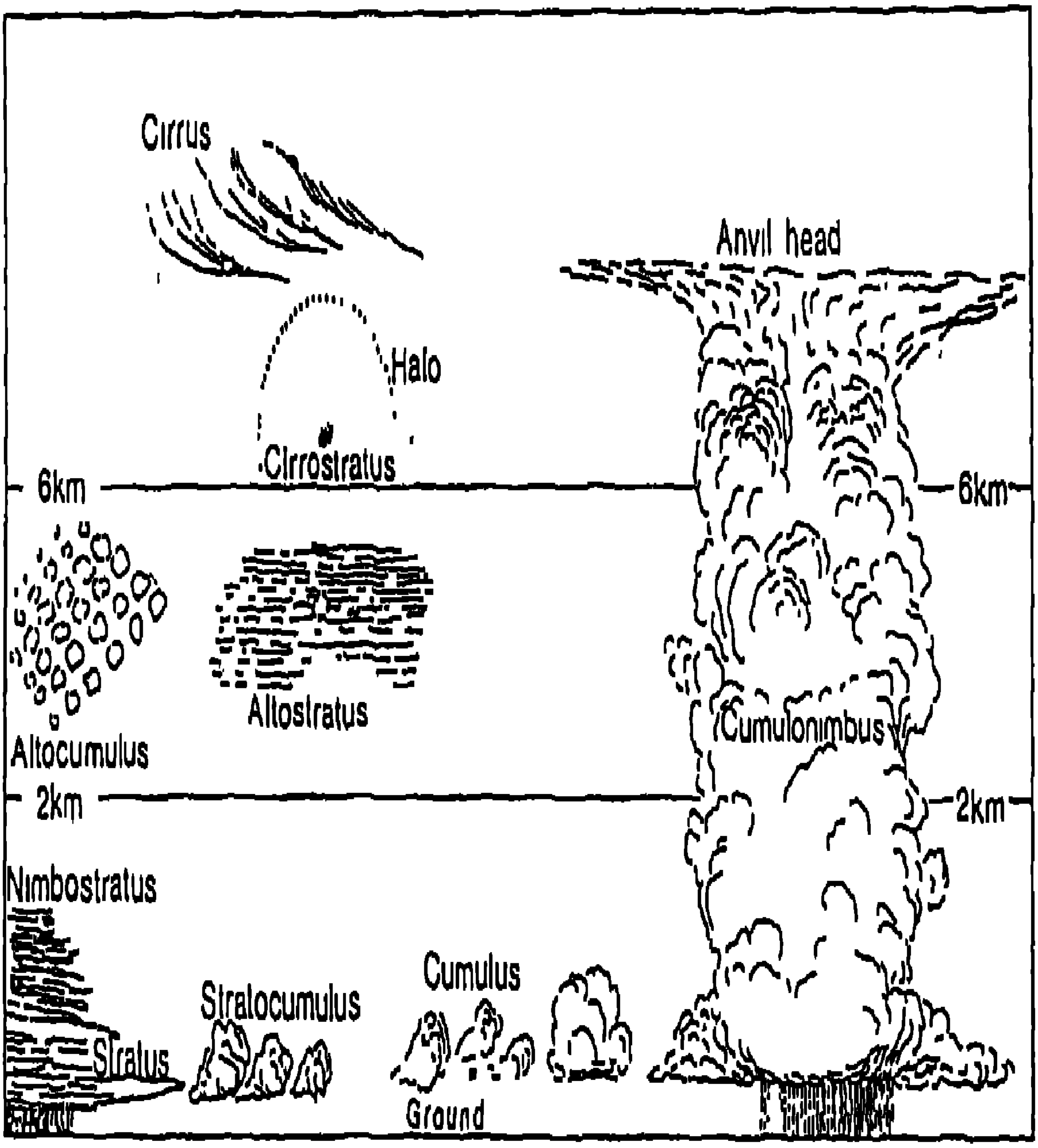


Figure Cloud types (after Budyoko in Bradshaw).

(ii) Cloud Forms in Unstable Air

(a) Cumuliform Clouds: Cumuliform clouds are separate heap like entities that grow vertically. They are formed in an unstable atmosphere and result from convective lifting of bodies of air, which cool adiabatically as they rise They have a distinctive flat base where condensation occurs in the rising air bubble The height reached by the tops of such clouds depends on the amount of moisture available and the conditions of stability and instability Three main types are distinguished according to their vertical development and height of their bases. Using composite names, a total of ten types or genera of clouds can be classified While many other cloud form have been named since the early 19th century, they can be related to the three main types and many of them are regarded as species of ten main genera There are also varieties of these species, which cover most eventualities, but it is important to view clouds as being formed in either stable or unstable conditions.

Classification and Characteristics of Clouds

Name	Symbol	Main Constituent	Level	Height of base (km)	Likely Temperature at Base (°C)	Appearance	Mode of Formation	Precipitation
Cirrus	Ci	Ice	High	5-13	-20 to -60	Detached delicate while filaments, often fibrous, larger ice crystals in trails		
Cirrocumulus	Cc	Ice	High	5-13	-20 to -60	While patch or layer with smaller granular or rippled elements		None
Cirrostratus	Cs	Ice	High	5-13	-20 to -60	Translucent cloud veil. Halo phenomena		
Altocumulus	Ac	Water (Some Ice)	Middle	2 - 7	+10 to -30	White-grey layer with shading or broken elements Sharp outlines	Widespread ascent, Often frontal	Little / none

Name	Symbol	Main Constituent	Level	Height of base (km)	Likely Temperature at Base (°C)	Appearance	Mode of Formation	Precipitation
Nimbostratus	Ns	Water (Some Ice)	Middle Low	1-3	+10 to –30	Grey-bluish sheet, uniform appearance many have layers of ice, water, may be in rows		Occasional
Nimbostratus	Ns	Water + Ice	Middle low	1 - 3	+10 to -15	Dark gray layer, rendered diffuse by falling rain		Persistent rain or snow
Stratocumulus	Sc	Water	Low	½ - 2	+ 15 to -5	Grey-white patchy sheet. May occur in long rows		Little/ none
Stratus	St	Water	Low	0 – ½	+20 to -5	Gray uniform layer	Cooling widespread at surface	Dizzle or none
Cumulus	Cu	Water	Middle Low	½ -2	+15 to -5	Detached clouds with sharp outlines. May grow vertically	Ground radiation leading to convection and instability	None if small showers
Cumulonimbus	Cb	Water + Ice	High Middle Low	½ - 2	+15 to -5	Huge towering clouds , dense, dark and mountainous, Top flattened spreading to anvil.		Heavy showers Thunder storms

1. Introduction

Once water droplets are initially formed, the process of its growth is far from simple and much remains to be explained In the early stages the solution effect is predominant and small drops grow more quickly than large once, but as the size of a droplet increases its growth rate by condensation decreases The radial growth rate obviously slows down as the drop size increases because there is an increasingly greater surface area to add to with every increment of radius. However, the condensation rate is limited by the speed with which the released latent heat can be lost from the drop by conduction to the air and this heat reduces the vapour gradient Moreover competition between droplets for the available moisture increasingly tends to reduce the degree of super saturation

These facts strongly suggest that the gradual process of condensation is inadequate to explain the rates of formation raindrops, which are often observed. For example, in most clouds precipitation develops within an hour. It must be remembered too that falling raindrops undergo evaporation in the unsaturated air below the cloud base A droplet of 0.1mm radius evaporates after falling only 150 m at a temperature of 5°C and 90 percent relative humidity, but a drop of 1 mm radius would fall 42 km before evaporating. It seems likely then that cloud droplets are not necessarily the immediate source of raindrops.

2. Theories of Growth of Raindrops

Numerous early theories of raindrop growth have met with objections For example, it was proposed that differently charged droplets could coalesce by electrical attraction, but it appears that distances between drops are too great and the difference between the electrical charges too small for this to happen. It was also suggested that large drops might grow at the expense of small ones, but observations show that the distribution of droplet size in a cloud tends to maintain a regular pattern, with the average radius between about 10 to 15 μm Another proposal was based on the variation of saturation vapour pressure with temperature such that if atmospheric turbulence brought warm and cold cloud droplets into close conjunction the super saturation of the air with reference to the cold drop surfaces and the under saturation with reference to the warm drop surfaces would cause the warm drops to evaporate and the cold ones to develop at their expense However, except perhaps in some tropical clouds, the temperature of cloud droplets is too low for this differential mechanism to

operate It shows that below about $-10°C$ the slope angle of the saturation vapour pressure curve is low. Another theory was that raindrops grow around exceptionally large condensation nuclei (such as have been observed in some tropical storms) Large nuclei, it is known, do experience a more rapid rate of initial condensation, but after this stage they are subject to the same limiting rates of growth that apply to all other atmospheric water drops The two main groups of current theories, which attempt to explain the rapid growth of raindrops, involve the growth of ice crystals at the expense of water drops, and the coalescence of small water droplets by the sweeping action of falling drops

2.1 Bergeron – Findeisen Theory

This theory forms an important part of the presently accepted mechanism of raindrop growth, and is based on the fact that the relative humidity of air is greater with respect to an ice surface than with respect to a water surface. As the air temperature falls below 0°C the atmospheric vapour pressure decreases more rapidly over an ice surface than over water. This results in the saturation vapour pressure over water becoming greater than that over ice, especially between temperatures of -5°C and -25°C where the difference exceed 0.2mb. If ice crystals and super cooled water droplets exist together in a cloud the latter tend to evaporate and direct deposition takes place from the vapour on the ice crystals (this is often described by meteorologist as sublimation, which properly refers to direct evaporation from ice.)

Just as the presence of condensation nuclei is necessary for the formation of water droplets, so *freezing nuclei* are necessary before ice particles can form – usually at very low temperatures (about -15°C to -25°C). Small water droplets can, in fact, be super-cooled in pure air to -40°C before spontaneous freezing occurs, but ice crystals generally predominate in clouds where temperatures are below about -22°C. Freezing nuclei are far less numerous than condensation nuclei; for example, there may be as few as 10 per liter at -30°C and probably rarely more than 1000 However, some become active at higher temperatures, Kaolinite, a common clay mineral, becomes initially active at -9°C and on subsequent occasions at -4°C The origin of freezing nuclei has been the subject of much debate but it is generally considered that very fine soil particles are a major source Another possibility is that meteoric dust provides the nuclei, although there seems to be no form evidence of a relationship between meteorite showers and rainfall Volcanic dust ejected into the upper stratosphere and troposphere during eruptions might be an additional terrestrial source Recent work shows that common biogenic aerosols emitted by decaying plant litter, in the form of complex chemical

compounds, serve as freezing nuclei In the presence of certain associated bacteria, ice nucleation can take place at only -2°C to -5°C

Once minute ice crystals have formed they grow readily by deposition from vapour, with different hexagonal forms of crystal developing at different temperature ranges The number of ice crystals also tends to increase progressively because small splinters become detached during growth by air currents become detached during growth by air currents and act as fresh nuclei. The freezing of super-cooled water drops may also produce ice splinters Ice crustals readily aggregate upon collision, due to their frequently branched (dendritic) shape, and tens of crystals may form a single snow flake. Temperatures between about 0°C and -5°C are particularly favourable to aggregation, because fine films of water on the crystals' surfaces freeze when two crustals touch, binding them together. When the fall-speed of the growing ice mass exceeds the existing velocities of the air up currents the snowflake falls, melting into a raindrop if it passes through a sufficient depth of air warmer than 0°C.

This theory seems to fit most of the observed facts, yet it is not completely satisfactory Cumulus clouds over tropical oceans can give rain when they are only some 2000 m (6500ft) deep and the cloud-top temperature is 5°C or more Even in middle latitudes in summer precipitation may fall from cumuli, which have no subfreezing layer (warm clouds). A suggested mechanism in such cases is that of 'droplet coalescence'.

2.2 Collision Theories

Alternative raindrop theories use collision, coalescence and 'sweeping' as the drop growth generator It was originally through that atmospheric turbulence by making cloud particles collide would cause a significant proportion to coalesce However, it was found that particles might just as easily break up if subjected to collisions and it was also observed that there is often no precipitation from highly turbulent clouds. Langmuir offered a variation of this simple collision theory by pointing out that falling drops have terminal velocities (typically 1-10 cm s^{-1}) directly related to their diameters such that the larger drops might overtake and absorb small droplets and that the latter might also be swept into the wake of the former and be absorbed by them Although coalescence is initially rather slow, the drop can reach 200 μm radius in 50 minutes; moreover, the growth rate is rapid for droplets with radii greater than 40 μm. Calculations show that drops must exceed 19 μm in radius before they can coalesce with other droplets, smaller droplets being swept aside without colliding The initial presence of a

few very large cloud droplets calls for the availability of giant nuclei (e.g salt particles) if the cloud top does not reach above the freezing level Observations show that maritime clouds do have relatively few large condensation nuclei (10-50μm radius) and a high liquid water content, whereas continental air tends to contain many small nuclei (~ 1 μm) and less liquid water Hence, rapid onset of showers is feasible by the coalescence mechanism in maritime clouds Alternatively, if a few ice crystals are present at higher levels in the cloud (or if seeding occurs with ice crystals coming from higher cloud layers) they may eventually fall through the cloud as drops and the coalescence mechanism comes into action. Turbulence, especially in cumuliform clouds, serves to encourage collisions in the early stages and cloud electrification also increases the efficiency of coalescence. Thus, the coalescence process allows a more rapid growth than simple condensation can provide and is, in fact, common in 'warm' clouds in tropical maritime air masses, even in temperature latitudes.

3. Precipitation Types

The above material can now be related to that of a discussion of precipitation types A convenient starting point is the usual division into three main types – convective, cyclonic and orographic precipitation – according to the primary mode of uplift of the air. Essential to this analysis is some knowledge of storm systems. These are treated in later chapters and the newcomer to the subject may prefer to read the following in conjunction with them

3.1 'Competitive type' precipitation: This is associated with towering cumulus (cumulus congestus) and cumulonimbus clouds Three subcategories can be distinguished according to their degree of spatial organization.

1. Scattered convective cells develop through strong heating of the land surface in summer, especially when low upper troposphere temperatures facilitate the release of conditional or convective instability. Precipitation, often including hail, is of the thunderstorm type, although thunder and lighting do not necessarily occur. Small areas (20 to 50km) are affected by the individual heavy downpours, which generally last for about 30 minutes to 1 hour

2. Showers of rain, snow or soft hail pellets may form in cold, moist unstable air passing over a warmer surface Convective cells moving with the wind can produce a streaky distribution of precipitation parallel to the wind direction, although over a period of several days the variable paths and intensities of the showers tend to obscure this pattern Two locations in which these cells may occur are parallel to surface cold front in the warm sector of

a depression (sometimes as a squall line) or parallel to and ahead of the warm front Hence the precipitation is widespread, though of brief duration at any locality.

3. In tropical cyclones cumulonimbus cells become organized about the center in spiraling bands Particularly in the decaying stages of such cyclones, typically over land, the rainfall can be very heavy and prolonged, affecting areas of thousands of square kilometers

3.2 'Cyclonic Type' precipitation

Precipitation characteristics vary according to the type of low-pressure system and its stage of development, but the essential mechanism is ascent of air through horizontal convergence of air-streams in areas of low pressure. In extra-tropical depressions this is reinforced by uplift of warm, less-dense air along an air-mass boundary Such depressions give moderate and generally continuous precipitation over very extensive areas as they move usually eastward in the westerly wind belts between about 40° and 65° path for 6 to 12 hours, whereas the belt in the rear give a shorter period of thunderstorm-type precipitation. Polar lows combine the effects of airstreams convergence and convective activity whereas troughs in the equatorial low-pressure area give convective precipitation as a result of airstreams convergence in the tropical easterlies.

3.3 Orgraphic precipitation

Orographic precipitation is commonly regarded as a distinct type, but this requires careful qualification Mountains are not especially efficient in causing moisture to be removed from airstreams crossing them, yet because precipitations falls repeatedly in more or less the same locations the cumulative totals are large. Orography, dependent on the alignment and size of the barrier, may cause (a) forced ascent on a smooth mountain slope, producing adiabatic cooling, condensation and precipitation, (b) triggering of conditional or convective instability by blocking of the airflow and upstream lifting; (c) triggering of convection by diurnal heating of slopes and upslope winds, (d) precipitation from low-level cloud over the mountains through 'seeding' of ice crystals or droplets from an upper-level feeder cloud; (e) increased frontal precipitation by retarding the movement of cyclonic systems and fronts. West coast mountains with onshore flow, such as the Western Ghats, India, during the south-west summer monsoon, the west coasts of Canada, Washington and Oregon; or coastal Norway, in winter months, supposedly illustrate smooth forced ascent, yet most of the other processes seem to be involved The limited width of the coastal ranges, with average wind speeds, generally allows insufficient time for the basic mechanisms of precipitation growth to operate

ADIABATIC PROCESS, STABILITY AND INSTABILITY

P. K. Mohapatra

1. Adiabatic Process of Cooling

When the temperature changes without any addition of subtraction of heat it is termed as adiabatic temperature change. Adiabatic temperature changes are brought about by an increase in volume and consequent consumption of energy, reducing the heat availability per unit volume, and hence, the temperature This type of cooling is brought about by ascent of air

An ascending saturated air cools at a rate of 9.8°C/km but as condensation starts the air starts cooling at a lower rate of 3.9°C/km So temperature changes occur as the air rises and falls but why should the air rise and fall? The ascent of the air will depend on the conditions of atmospheric stability and instability

2. Adiabatic Temperature Changes

Temperature changes involving no subtraction or addition of heat is called 'adiabatic temperature changes (greek; 'aciabatos'- for impassable, indicating that heat energy is not lost through the rising body of air). Air is a poor thermal conductor and as the air parcel moves vertically, it tends to retain its own thermal identity as a whole, which distinguishes it from the surrounding air masses When air rises, it expands because of less weight of air upon it at high altitudes. Expansion necessarily entails increase in volume. A volume increase involves work (as the air is pushing aside the surrounding air) and consumption of energy, thus, reducing the heat available per unit volume, and hence, the temperature decreases.

The rate at which temperature decreases in a rising, expanding air parcel is called the Adiabatic Lapse Rate (ALR). It is different from normal lapse rate in that it represents the temperature that would be recorded by a thermometer carried through the atmosphere by a balloon or a kite, while ALR represents cooling of a rising mass of air. If the upward movement by expansion will cause the temperature of the mass to fall at a rate of 9 8°C/km called the Dry Adiabatic Lapse Rate (DALR) However, prolonged reduction of the temperature invariably produces condensation and when this happens latent heat is released This increase in heat energy slows the rate of temperature decrease within the rising body Therefore, the air parcel cools more slowly than the DALR The rate of cooling depends on water vapour content of the air This lower cooling is called the Saturated Adiabatic Lapse Rate (SALR) and varies from about 3°C/km for very humid air to about 9° C/km for air having a low mixing ratio The

SALR depends on the original temperature of the air as it left the ground Warmer air at the ground takes up more moisture by evapotranspiration than colder air, so that when it gets to dew point, the warmer air has more water vapour to condense and more latent heat to release

3. Stability and Instability: As the temperature of the air rises it expands and its density decreases. If the air is warmer than its surroundings, it will be lighter and will have a tendency to rise. On the contrary, if it is cool, it will become heavy and hence, will have a tendency to sink, the air, which is rising, or falling experience temperature change itself. These may result in the air, returning to the same temperature as its surroundings It is then said to be stable; or becoming increasingly warmer than its surroundings when it is said to be unstable.

4. Stability: Thus, when the air resists vertical movement and tends to remain in its original position, it is said to be stable. Normally, an air mass is most stable when colder and drier air underlies warmer air. Under such an arrangement the denser air is below the lighter air and upward movement is very difficult. It is for this reason that an air mass, in which a temperature inversion exists, has a high degree of stability.

There are two ways in which stability can be promoted

(i) If an air mass is cooled from below through radiation and conduction to a cold underlying surface; the density of lower air is relatively increased and the stability also increases.

(ii) When the air is subsiding and spreading laterally producing horizontal divergence and high pressure This process of stabilization occurs in high-pressure anticyclonic storm system Noting its vertical temperature distribution or lapse rate and comparing it with adiabatic rate can determine the relative stabilıty of an air mass They are more easily comprehended in the form of a diagram; they are plotted on graphs called Tephigram. When the environmental lapse rate (ELR) is less than the dry adiabatic lapse rate (DALR) and saturated adiabatic lapse rate (SALR), the air is said to be absolutely stable

5. Instability: When the air does not resist upward vertical displacement but has a tendency to move upward, a condition of instability prevail Under the condition of instability clouds form and precipitation takes place. Instability is characteristics of warm humid air in which there are rapid vertical decreases in temperature and humidity, i e , a steep lapse rate. When the lapse rate is greater than adiabatic rate of 9 8° c/km, a condition of instability prevails Air is defined as unstable if the ELR exceeds DALR Instability may be developed in a variety of ways,

(i) When the air become lighter than the surrounding environmental air as a result of its warmth and humidity.

(ii) When convergence takes place, the warm air rises

(iii) When air is forced to rise over some obstacle, for example, a mountain.

Instability can be of three types,

(a)Absolute Instability: When the ELR is greater at every level than the DALR the displaced parcel of air will continue its movement upward till the point where the temperature of the displaced air is equal to that of the surrounding air The state of continued vertical movement of the rising air is called absolute instability.

(b)Conditional instability: When humid air, that is mildly stable, is forced to rise over mountain barrier or over colder wages of air, the resulting condensation will add so much heat to the ascending air that it becomes actually unstable and continues to rise with heavy precipitation. Such humid air, which was initially stable but was made unstable as a result of condensation associated with forced ascent, is said to be conditionally unstable.

(c) Potential instability: When large air masses, which are moist in their lower layers but dry in their upper position, undergo bodily lifting, such as at frontal surface or on striking mountains, the dry upper part will experience drop in temperature at DALR while the lower parts become saturated and cool at SALR The different rate of cooling of different parts radically alters the temperature distribution throughout the mass transforming an initially stable situation into unstable one. This instability, known as potential instability, is fairly common among warm air masses, which have picked up substantial amount of moisture in their lower layers while passing over sea areas.

CYCLONES AND ANTICYCLONES

P. K. Mohapatra

1. Temperate Cyclones and Fronts

Large eddies, both cyclonic and anticyclonic, are essential features of the general circulation of atmosphere. The secondary atmospheric circulation, which includes the mid latitude depressions and cyclones, produce the most noticeable changes in weather in temperate regions. Mid latitude depressions, known also as temperate cyclones, extra tropical cyclones, frontal depressions, play a very important role in the transfer of energy from the Equator to the poles

1.1 Origin of Depressions

The origin of depressions can be considered in terms of Polar Front Theory and its relations with upper air circulation

(i) Polar Front Theory: The Polar Front Theory is the name given to a series of papers concerning the processes in operation within a mid latitude depression produced by a group of Norwegian meteorologists – V. Bjerknes, J Bjerknes and Solberg. The fundamental notion within the Polar Front Theory is that many of the day-to-day weather variations in middle latitudes are connected with the movement and evolution of the boundaries between air masses which they called fronts. The principal front from the geographical standpoint is the Polar front which is the interface between the tropical and polar air It is not continuous around the Earth but is interrupted by regions where the transition between tropical and polar air is gradual. The front between the Arctic and Polar air masses is called the Arctic front It is also not continuous around the Earth

According to the Polar Front Theory, cyclones or depressions form where a wave develops on the Polar front (hence, also known as wave cyclone), which allows a tongue of warmer Tropical air to penetrate into the Polar air mass The whole process of birth of depression is called frontogenesis while its decay is called frontolysis The initial stage of wave cyclone (or frontal depression) is a slight deformation of the Polar front producing a wave Topographic features, temperature contrasts between land and sea, the ocean current contrasts or nearby disturbances, frequently induce the deformation For this reason, certain geographical regions are preferred areas for formation of cyclonic waves

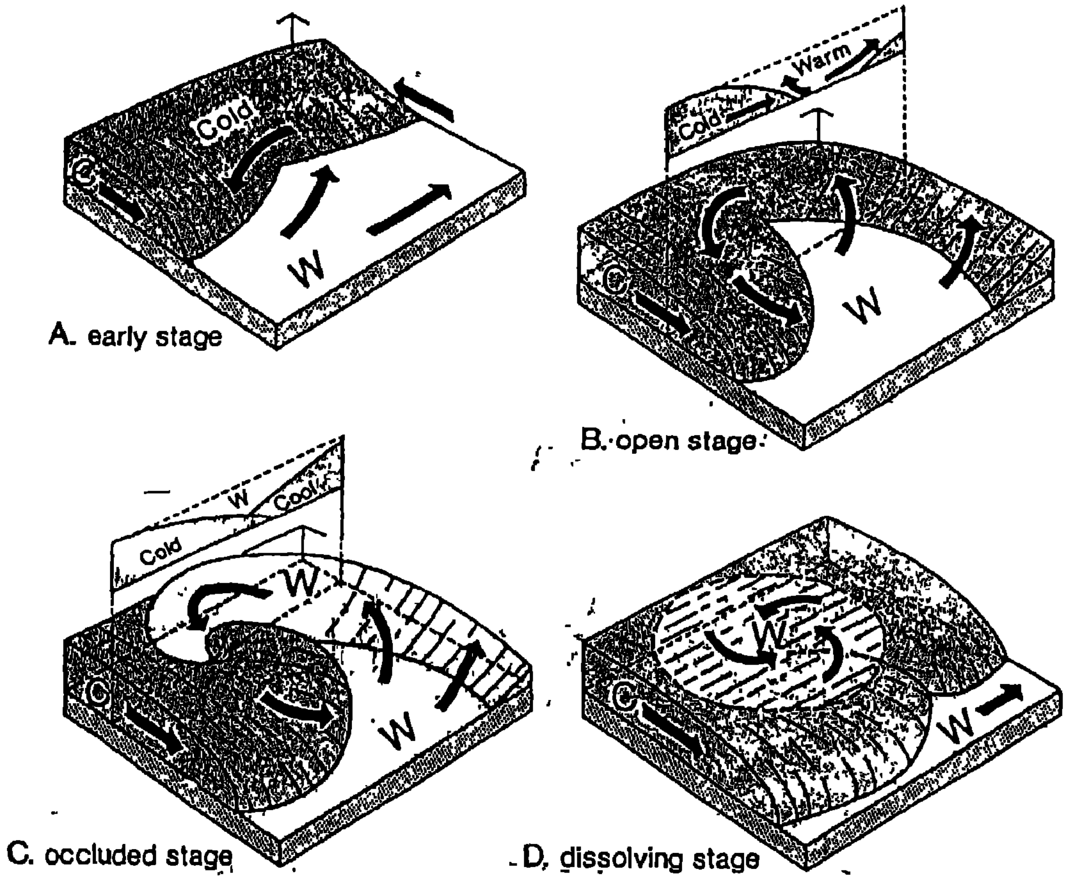


Figure ,The Polar Front Theory (after Bjerknes).

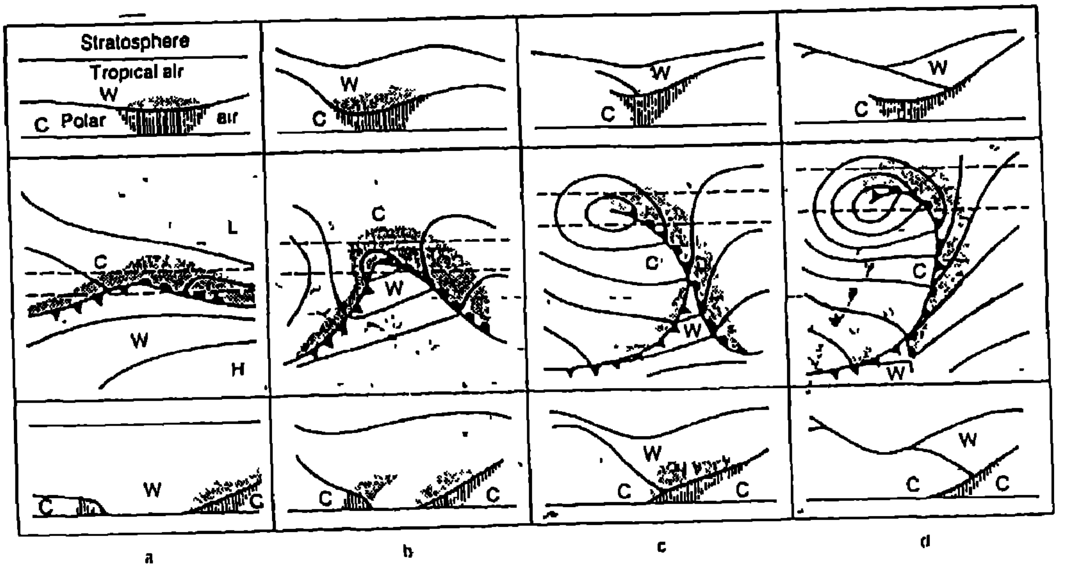


Figure Stages in the evolution of a frontal depression according to the Polar Front Theory. The middle diagrams represent surface weather charts at different times; the areas of cloud are shown in grey, the areas of precipitation are shown as pecked lines. Upper and lower diagrams represent cross-sections drawn at the positions of the pecked lines in the middle diagrams.
(a) growing wave; (b) mature wave; (c) Partially occluded wave; (d) occluded wave.
(W: warm; C: cold).

If the wave is dynamically unstable, it grows in amplitude with the warm air creating a pole ward bulge into the cold air, which begins to flow round the rear of the wave. The wind at this time is blowing from cold to warm region behind the wave and from warm to cold region ahead of it. The whole depression is moving eastward, parallel to the isobars As the cyclone develops, it replaces more and more cold air Within 24 hours of the initial disturbance of the front, a well-defined warm sector depression will have developed with a warm front, along which warm air ascends over a wedge of colder air, and cold front, where cold air displaces the warm air by under running the warm and lighter tropical air mass

Within the depression, the air behind the cold front moves faster than the air that is receding ahead of the warm front. This causes the cold front to move at a faster speed than the warm front and begins to overtake, it starting at the top of the warm sector and working outwards. When this process occurs the air in the warm sector is pinched out and lifted bodily off the ground. The ascent of air creates low pressure at the surface with isobars surrounding the center of low pressure The winds near ground level blow across the isobars, and thus, air spirals inwards and upwards towards the center of depression Lifting of the air leads to adiabatic cooling producing clouds and rain Eventually, all that remains of the once vigorous depression is a roughly circular anticlockwise swirl of air in the upper troposphere, often referred to as cut-off low.

Once the warm air has been finally lifted off the ground, the cold air from behind the depression comes into contact with the cold air in the front It is unlikely that the two air masses will be exactly the same and so the zone of separation between the two is referred to as occlusion or occluded front Such an occlusion can be either cold or warm A cold occlusion occurs when the air behind the occluded front is colder than the air ahead of it and the warm occlusion when the reverse is the case

The Norwegian meteorologist also found that temperate cyclones never appear alone It is frequently a succession of frontal depressions, often at different stages of development occurring on the Polar Front Such a series of depressions up to seven in number is known as a depression family They occur frequently over Atlantic and Pacific oceans and give spells of unsettled weather lasting for a week or more. The depression, which succeeds the original one, is called secondary depressions along the trailing edge of an extended cold front Usually each successive member of a family of depressions follows a course, which is on equator ward side

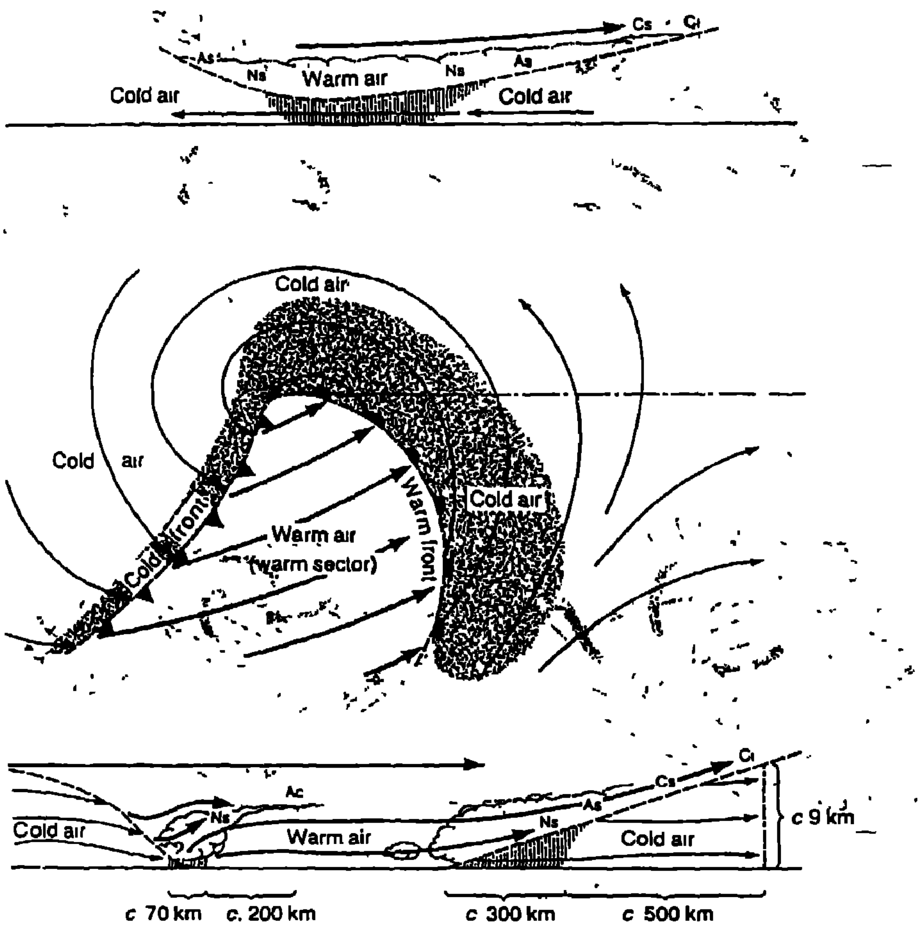


Figure — An idealised model of a warm-sector depression. Upper diagram: vertical cross-section north of wave depression. Middle diagram: representation of frontal wave and streamlines on surface chart. Lower diagram: vertical cross-section through warm sector. Shading indicates areas of precipitation.

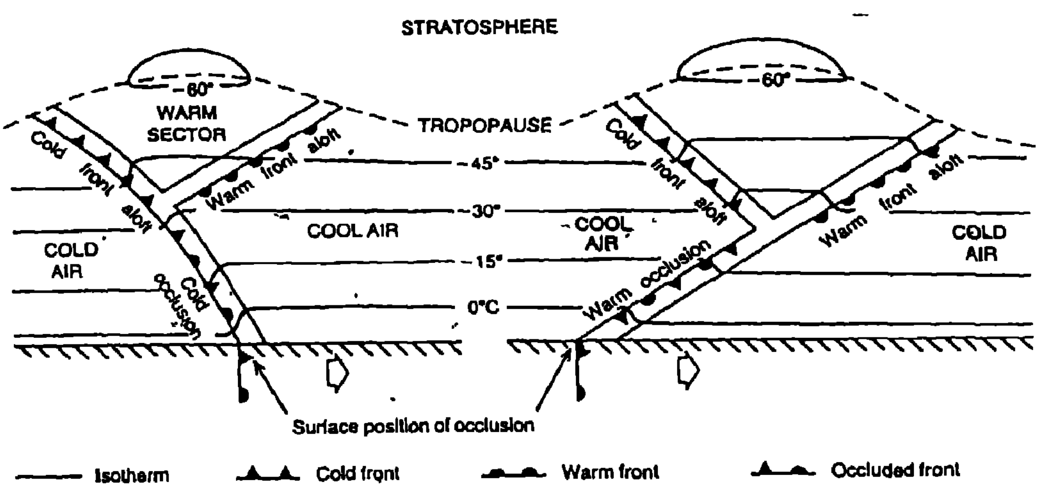


Figure — Schematic cross-sections through a cold occlusion (left) and a warm occlusion (right) (after Musk).

of its predecessor as the Polar air pushed farther south to the rear of each depression in the series. Mid latitude non-frontal depressions include lee depressions which form in the lee of major topographical barriers, thermal lows which result from unequal heating, particularly, of land areas in summer and Polar air depressions which sometimes develop in cold unstable air passing over a warm sea surface. Another pattern of development takes place on the arm front particularly at the point of occlusion as a separate waveforms running ahead of the parent depression. This type of secondary depressions is more likely with very cold air ahead of the warm front.

The Polar Front Theory is fundamentally correct, but it was based essentially on ground-based observations, and thus, there were many errors i.e.

1 The upper air circulations are very vague. This was due to the lack of upper air observations at that time Jet Streams were not known and so their role was not considered.

2 It lacks a full explanation of many questions as to why the frontal surface should distort in the way it does? What happens to the warm sector air that is lifted off the ground during the occlusion process? Why is the pressure fall in deep depressions so large? The Polar Front Theory argues that pressure fall in depressions is due to replacement of cold air by less dense warm air but this is insufficient to account for it.

3 Lastly, it is not even necessary that depressions should form from pre-existing fronts.

(ii) Upper – Level Flow in Relation to Wave Cyclone: When the models of wave cyclone were first developed, observations of the temperature structure and flow patterns aloft were practically non-existent Since then, upper air observations have clarified the relationship between the frontal waves and the flow at upper levels At the same time, the observations have made it clear that other processes frequently lead to formation of cyclones without the prior existence of fronts. Once the cyclone forming process is under way it may give rise to formation of fronts within a cyclone There are, thus, two general ways in which cyclones may form, (i) frontal waves at low levels that induce wave-shaped flow patterns aloft, and (ii) one that produce low pressure centers at lower levels and subsequently may draw air-masses together producing fronts in them

2. Tropical Cyclones

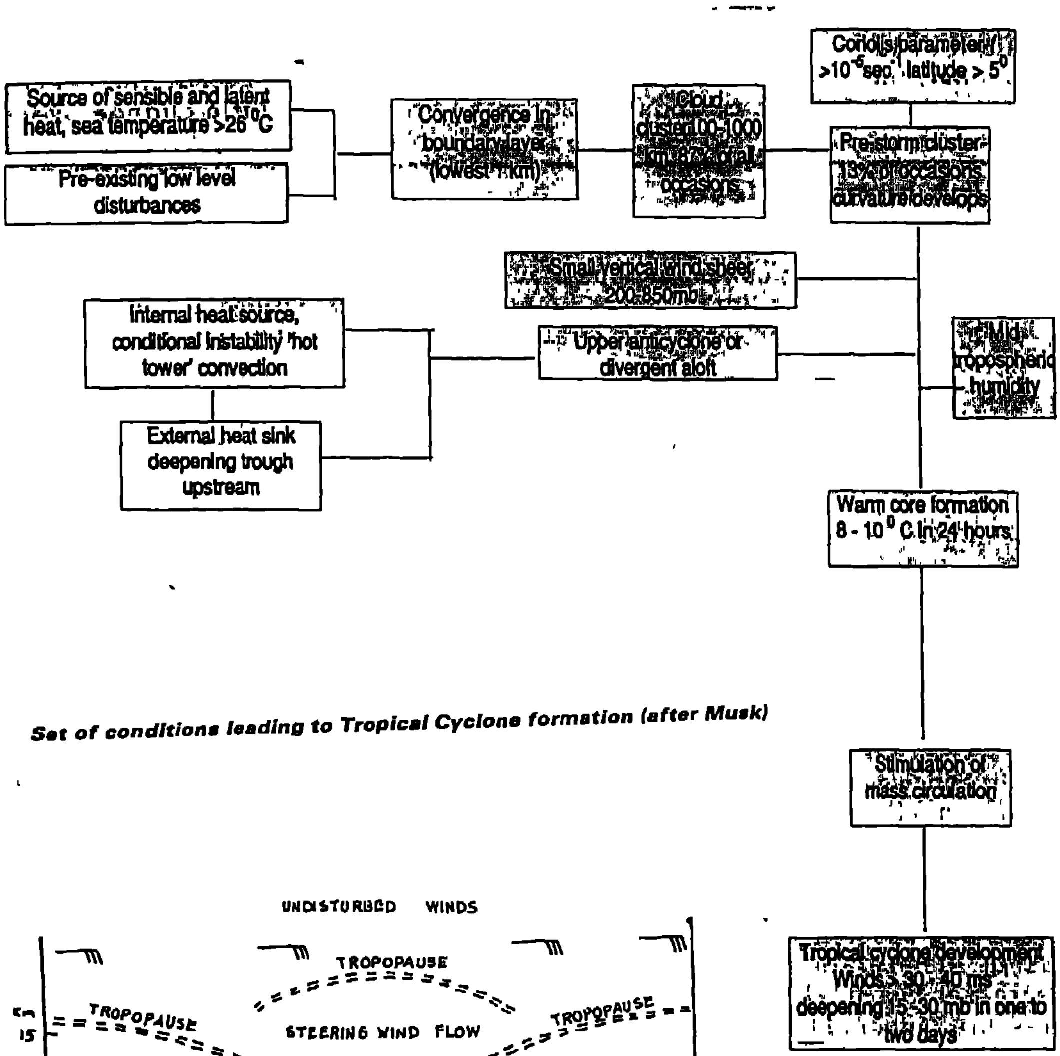
2.1 Hurricanes

The most notorious type of cyclone is the tropical hurricane (or typhoon) Some 80 or so cyclones each year are responsible, on average, for 20,000 fatalities, as well as causing immense damage to property and a serious shipping hazard, due to the combined effects of high winds, high seas, flooding from the heavy rainfall and coastal storm surges As result, considerable attention has been given to forecasting their development and movement so that their origin and structure are beginning to be understood. Naturally the catastrophic force of a hurricane makes it a very difficult phenomenon to investigate, but some assistance is now obtained from aircraft reconnaissance flights sent out during the 'hurricane season', from radar observations of cloud and precipitation structure, and from satellite photography.

The typical hurricane system has a diameter of about 650 km (400 miles), less than half that of a mid-latitude depression, although typhoons in the Western Pacific are often much larger The central pressure at sea level is commonly 950mb and exceptionally falls below 900 mb. Cyclonic-intensity storms are defined as having maximum sustained surface winds exceeding 33 ms^{-1} (74 mph) and in may storms they exceed 50 ms^{-1} (120mph) The great vertical development of cumulonimbus clouds with tops at over 12,000 m (40,000 ft) reflects the immense convective activity concentrated in such systems Radar and satellite studies show that the convective cells are normally organized in bands which spiral inward towards the center

Although the largest hurricanes are characteristic of the Pacific, the record is held by the Caribbean hurricane 'Gilbert' which was generated 320 km (200 miles) east of Barbados on 9 September 1988 and moved westward at an average speed of 24-27 km hr^{-1} (15-17 mph), dissipating off the east coast of Mexico. Aided by an upper troposphere high-pressure cell north of Cuba, hurricane its center dropped to 888 mb (the lowest ever recorded in the western hemisphere) and maximum wind speeds near the core were in excess of 55 ms^{-1} (125 mph) More than 500 mm of rain fell in the highest parts of Jamaica in only 9 hours However, the most striking feature of this record storm was its size, being some three times that of average Caribbean hurricanes At its maximum extent the hurricane had a diameter of 3500km, disrupting the ITCZ along more than one-sixth of the earth's equatorial circumference and drawing in air from as far away as Florida and the Galapagos Islands

The main tropical cyclone activity in both hemispheres is in late summer and autumn during times of maximum northward and southward displacements of the Equatorial trough



Set of conditions leading to Tropical Cyclone formation (after Musk)

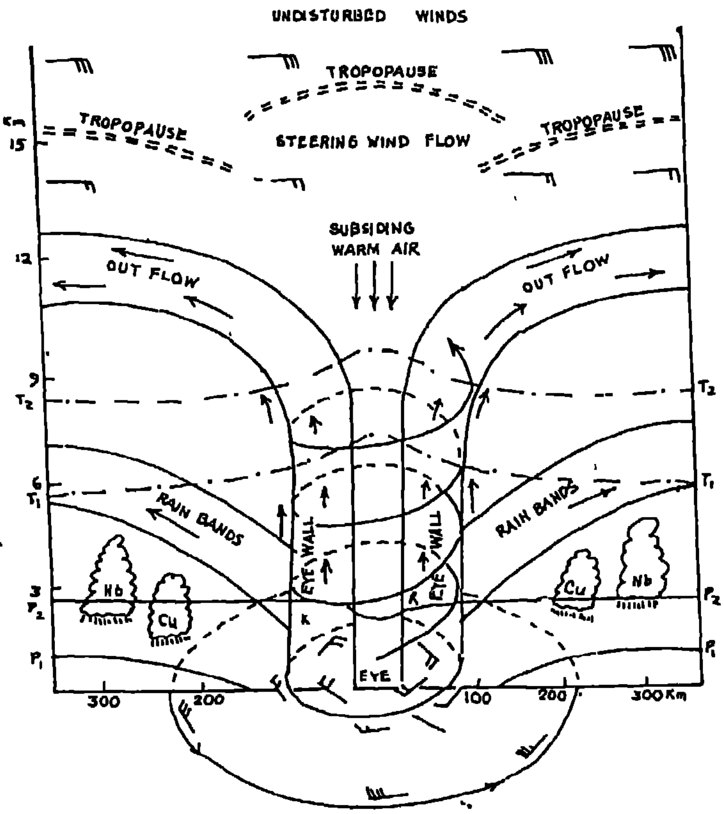


Fig .A Schematic representation of vertical structure of a mature cyclonic storm

A small number of storms affect both the western North Atlantic and North Pacific areas as early as May and as late as December, and have occurred in every month in the latter area. In the Bay of Bengal, there is also a secondary early summer maximum.

A number of conditions are necessary, even if not always sufficient, for hurricane formation. One requirement is an extensive ocean area with a surface temperature greater than 27^0 C (80^0 F). Cyclones rarely form near the equator, where the Coriolis parameter is close to zero, or in zones of strong vertical wind shear (i e beneath a jet stream), as both factors inhibit the development of an organized vortex There is also a definite connection between the seasonal position of Equatorial Through and zones of hurricane formation, which is borne out by the fact that no hurricanes occur in the South Atlantic (where the trough never lies south of 5^0S) or in the southeast Pacific (where the trough remains north of the equator) On the other hand, satellite photographs over the north-east Pacific show and unexpected number of cyclonic vortices in summer, many of which move westwards near the trough line about 10^0 – 15^0 N About 60 percent of tropical cyclones seem to originate 5^0 – 10^0 latitude pole ward of the Equatorial Trough n the doldrums sectors, where the trough is at least 5^0 latitude from the equator The development regions of hurricanes mainly lie over the western sections of the Atlantic, Pacific and Indian Oceans where the subtropical high-pressure cells do not cause subsidence and stability and the upper flow is divergent. About twice per season, in the western equatorial Pacific, tropical cyclones form almost simultaneously in each hemisphere near 5^0 latitude and along the same longitude. The cloud and wind patterns in these cyclone 'twins' are roughly symmetrical with respect to the equator

Early theories of hurricane development held that convection cells generated a sudden and massive release of latent heat to provide energy for the storm Although convection cells were regarded as an integral part of the hurricane system, their scale was thought to be too small for them to account for the growth of a storm hundreds of kilometers in diameter Recent research, however, is modifying this picture considerably Energy is apparently transferred from the cumulus-scale to the large-scale circulation of the storm through the organization of the clouds into spiral bands, although the nature of the process is still being investigated. There is now ample evidence to show that hurricanes form from pre-existing disturbances, but while many of these disturbances develop as closed low-pressure cells few attain full hurricane intensity The key to this problem is high-level outflow This does not require an upper troposphere anticyclone, but can occur on the eastern limb of an upper trough in the westerly This outflow in turn allows the development of very low pressure and high wind speeds near

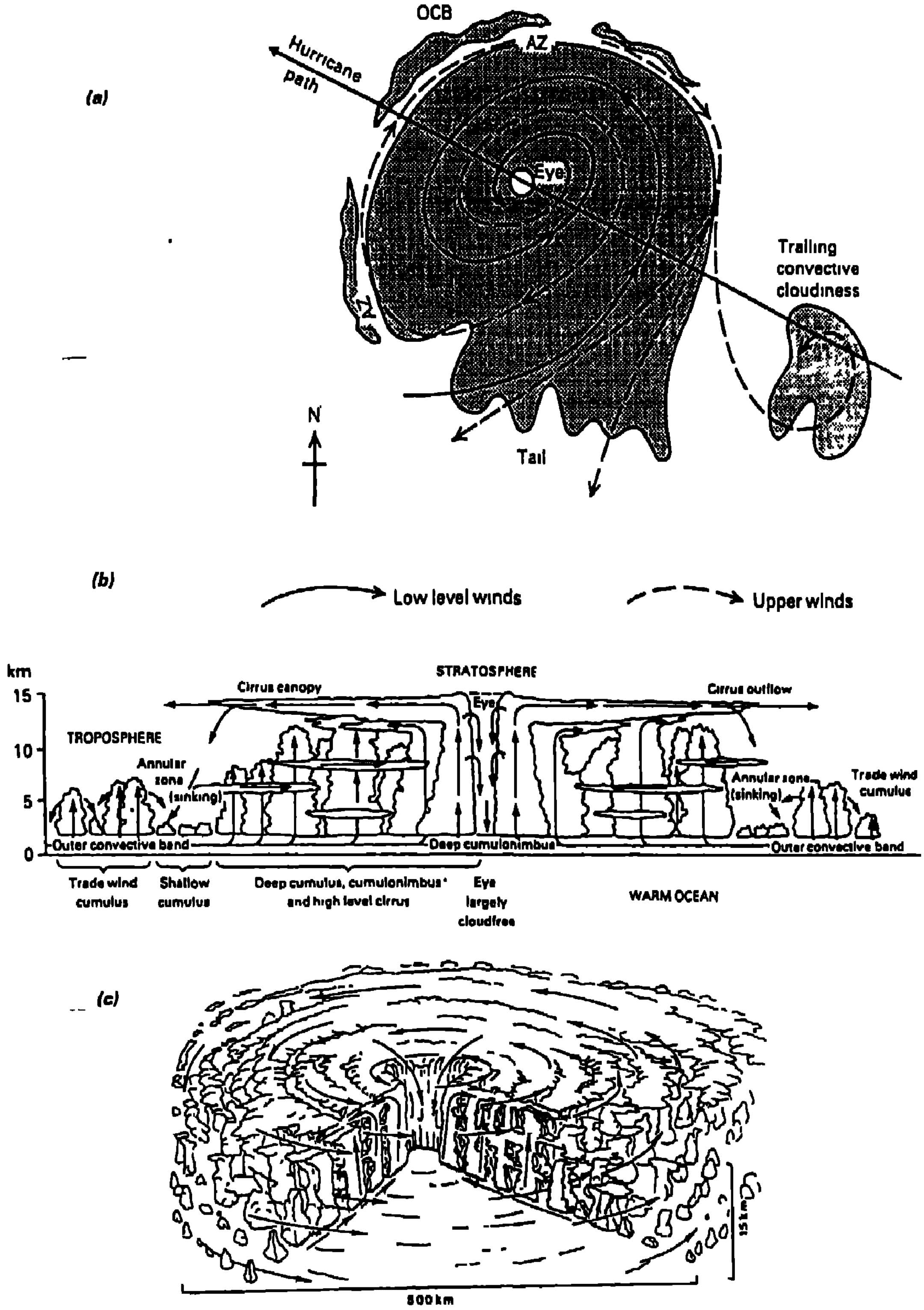


Figure ***Tropical cyclones in plan (a); profile (b); and three dimension (c)***

the surface A distinctive feature of the hurricane is the warm vortex, since other tropical depressions and incipient storms have a cold core area of shower activity. The warm core develops through the action of 100-200 cumulonimbus towers releasing latent heat of condensation, about 15 percent of the area of cloud bands is giving rain at any one time. Observations show that although these 'hot towers' form less than 1 percent of the storm area within a radius of about 400 km (230 miles), their effect is sufficient to change the environment The warm core is vital to hurricane growth because it intensifies the upper anticyclone, leading to a 'feedback' effect by stimulating the low-level influx of heat and moisture, which further intensifies convective activity, latent heat release and therefore the upper-level high pressure. This enhancement of a storm system by cumulus convection is termed conditional instability of the second kind The thermally direct circulation converts the heat increment into potential energy and a small fraction of this – about 3 percent – is transformed into kinetic energy The remainder is exported by the anti-cyclonic circulation at about the 12 km (200-mb) level

In eye, or innermost region of the storm adiabatic warming of descending air accentuates the high temperature, although since high temperatures are also observed in the eye-wall cloud masses, subsiding air can only be one contributory factor Without this sinking air in the eye, the central pressure could not fall below about 1000mb The eye has a diameter of some 30-50km (20-30 miles), within which the air is virtually calm and the cloud cover may be broken The mechanics of the eye's inception are still largely unknown If the rotating air conserved absolute angular momentum, wind speeds would become infinite at the center and clearly this is not the case The strong winds surrounding the eye are more or less in cyclostrophic balance, with the small radial distance providing a large centripetal acceleration The air rises when the pressure gradient can no longer force it further inward It is possible that the cumulonimbus anvils play a vital role in the complex link between the horizontal and vertical circulations around the eye by redistributing angular momentum in such a way as to set up a concentration of rotation near the center

The supply of heat and moisture combined with low frictional drag at the sea surface, the release of latent heat through condensation and the removal of the air aloft are essential conditions for the maintenance of hurricane intensity As soon s one of these ingredients diminishes the storm decays This can occur quite rapidly if the track (determined by the general upper troposphere flow) takes the vortex over a cool sea-surface or over land In the latter case the increased friction causes greater cross-isobar air motion, temporally increasing

the convergence and ascent At this stage, increased vertical wind shear in thunderstorm cells may generate tornadoes, especially in the northeast quadrant of the storm (in the northern hemisphere) However, the most important effect of a land track is that cutting off of the moisture supply removes one of the major sources of heat. Rapid decay also occurs when cold air is drawn into the circulation or when the upper-level divergence pattern moves away from the storm.

Hurricanes usually move at some 16-24 kmph (10-15 mph), controlled primarily by the rate of movement of the upper warm core. Commonly they recurve pole ward around the western margins of the subtropical high-pressure cells, entering the circulation of the westerly, where they die out or degenerate into extra tropical depressions Some of these systems retain an intense circulation and the high winds and waves can still wreak havoc This is not uncommon along the Atlantic coast of the United States and occasionally eastern Canada, Similarly, in the western North Pacific; re-curved typhoons are a major element in the climate of Japan and may occur in any month There is an average frequency of twelve typhoons per year over southern Japan and neighboring sea areas.

The hurricane develops from an initial disturbance, which, under favorable environmental conditions, grows first into a tropical depression and then a tropical storm (with wind speeds of 17-33ms^{-1} or 39-73 mph). The tropical storm stage may persist 4-5days, whereas the hurricane stage usually lasts for only 2-3 days (4-5 days in the western pacific) The main energy source is latent heat derived from condensed water vapour, and for this reason hurricanes are generated and continue to gather strength only within the confines of warm oceans. The cold-cored tropical storm is transformed into a warm-cored hurricane in association with the release of latent heat in cumulonimbus towers, and this establishes or intensifies an upper troposphere anticyclonic cell. Thus high-level outflow maintains the ascent and low-level inflow in order to provide a continual generation of potential energy (from latent heat) and the transformation of this into kinetic energy The inner eye, which forms by sinking air, is an essential element in the life cycle

3. Anticyclones

3.1 Galton first introduced the term 'anticyclone' in 1861 to describe cells of high pressure which had roughly concentric isobars and had characteristics opposite (anti) to that of cyclones or depressions Anticyclones are part of global atmospheric circulation and play a very important role in the transfer of energy from the Equator to the poles These are part of the eddies that transfer momentum between poles and equator and restore global equilibrium

These rotating systems migrate from one area to another with Rossby waves. In the process they transfer angular momentum and assist in maintaining a balance between the wind regimes The maximum transfer takes place at 30^0 lat.

3.2 Characteristics

(i) Anticyclones have high pressure as the air is subsiding. The pressure goes on decreasing away from the center The pressure difference between the center and periphery of anticyclone ranges between 10-20 mb

(ii) Because of high pressure the wind diverges from the center creating a clockwise circulation in the Northern Hemisphere and counter clockwise in the Southern Hemisphere.

(iii) Even though the gradient wind speed is greater for an anticyclone than for a cyclone with same horizontal pressure gradients, anticyclones usually have light winds because their pressure gradients are relatively small.

(iv) The anticyclones are dominated by subsidence throughout most of the troposphere but especially between 1.5 and 8km. The air does not sink right to the ground but approximately to 0.5 – 1.5 km above the surface. Te sinking is the result horizontal convergence aloft (forward side of the ridge in upper westernizes). The subsiding air in the center of anticyclone warms adiabatic ally, and thus, its temperature rises and relative humidity decreases.

(v) There is little temperature contrast across the highs.

(vi) No clouds (startups sometimes) are present as they tend to evaporate Further, the temperature inversion (subsidence type) promotes stability and restricts the vertical development of any cloud, which might form by turbulent mixing in the lowest layers of by convection.

(vii)Thus, anticyclones do not experience any precipitation and tend to by dry.

(viii)Anticyclones are commonly slow moving, persistent or stationary and so can bring settled weather for a few days or weeks at a time.

(ix)Anticyclones are generally larger (up to 3000 km across)

In short anticyclones are generally larger slow moving and more persistent with a high pressure at the center but with a weaker pressure gradient and light variable winds diverging from the center, and thus, have quite dry stable weather conditions and relatively clear skies

CLIMATE OF INDIA

B. S Mallasamanta

1. Introduction

Climate of India is characterized by the monsoon rhythm i.e., the rhythm of seasonal change. It affects the lifestyle, economic and socio-cultural life of the Indians The rural population of India comprising about 80% of its population depends on agriculture and allied activities. Baring few places where irrigation facilities are available, most of the agricultural lands still depend directly on monsoon. Failure of monsoon affects the entire socio-economic structure of India

India's' location, peninsular shape and vastness in size result in diversified climatic conditions in different parts of the country On the basis of temperature and rainfall distribution, India climate could be grouped into six seasonal patterns of climate.

1. April to Mid-June . Hot weather season
2. Mid-June to Mid-August Rainy season
3. Mid-August to Mid-September · Period of retracting monsoon.
4. Mid-September to Mid-November Autumn
5. Mid-November to Mid-February . Winter
6. Mid-February – End of March : Spring

Monsoon is a type of air mass characterized as tropical maritime and tropical continental types depending on their origin over water bodies and landmasses respectively Monsoon results due to change in the direction of airflow During rainy season most parts of India receive rainfall though with varying intensities due to S.W monsoon Similarly, northeast monsoon brings cold weather conditions Besides, climate of India is also greatly modified by the influence of jet stream The air movement is from the ocean to land during summer while the air movement is from land to ocean during water

2. Genesis and Origin of Monsoon

Indian landmass receives more heat from mid-March onwards. Due to more earth radiation, a low-pressure cell develops over central and northern India with its center located over northwestern part of India i e , over Rajsthan, Punjab, Haryana etc. Another low-pressure center develops over Tibet known as TLCZ i e Tibetan Lee Convergence Zone by the MONEX expedition

During this period pressure remains higher over the water bodies surrounding India mainly over Indian Ocean with its center over Madagascar. Pressure difference between low-pressure over north and northwestern parts of India attract the rain bearing air streams from the high-pressure areas Since this air currents origin in the S E Trade wind belt, they are influenced by its direction and flow in southeast direction After crossing the equator, they take a right angle turn (due to Ferrel's law based on coriolis force) and move from southwest direction in northern hemisphere. These air currents are highly saturated due to its movement over water bodies This air movement from S.W direction comes in contact against the southern tip of the Western Ghat Mountains in Kerala. The air currents are forced to rise which causes condensation and heavy rainfall. The first outburst of monsoon rains in India takes place near Kerala coast around 1st of June known as the "Bursting of Indian monsoon. Off the coast of Kerala, the air currents are divided into two branches, one moving over Arabian Sea while the other mores over Bay of Bengal known as the Bay of Bengal branch of Southwest

The Arabian Sea branch comes heavy rainfall in the windward side of the Western Ghats as it tries to enter into the Indian landmass. Due to the height of the Western Ghats, the air currents are unable to enter the land mass and blow along its western margin The other side of the Western Ghats remains a rain shadow area because of its leeward location The Arabian Sea branch enters into the landmass through the mountain bears near Gulf of Cambay and moves to the low-pressure center over northwest India Due to the absence of any mountain barrier, the air currents are unable to cause any rainfall. There are great mountain ranges in the path of movement of these currents like the Vindhyas, the Satpuras, the Aravallis etc but they all lie parallel to the monsoon airflow and are unable to obstruct the airflow to cause orographic rainfall Hence, no rainfall takes place in this region, which causes the dryness of this region

The Bay of Bengal branch moving in northerly direction changes its direction to northeast due to cariolis force. These saturated air currents of southwest monsoon come in contact against the northeastern Himalayas specially the mountains like Garo, Khasi and Jayanti hills etc As a result heavy rainfall takes place in this part of India with Mausiram and Cherapunji receiving the highest rainfall in the world Here the annual average rainfall varies between 120 to 1300 cms. Due to the northeastern syntaxes of the Himalayas and the great height of the mountains, the airstreams take a westward turn and try to reach the Tibetan Plateau low-pressure center This causes rainfall, which decreases from east to west As a result the moisture content of the airstreams decreases and western UP remains a semi-arid region By

the type the Bay of Bengal branch reaches the low pressure over northwestern part of India, there is practically no moisture left which results in arid condition over this part.

In the meantime the low-pressure cell, which developed over northwestern part of India, has developed into a trough with its tail extending over northern Orissa, West Bengal and Bihar. This attracts a part of the Bay of Bengal branch to enter through the trough and move towards the low-pressure center Due to the presence of the Eastern Ghat mountains rainfall takes place in these state, the amount of which gradually decreasing from the coast to the interior and by the time these air currents reach Rajasthan area, there is practically no moisture left in the airstreams to cause any rainfall. As a result this part remain dry. All the three branches of southwest monsoon fail to cause any rainfall in this part, which has resulted in the formation of Thar Desert in Rajsthan

By the time these branches reach this part of India, it is already August and the landmass experience a reversal pressure distribution due to southward migration of the sun. As a result, low pressure prevails over the ocean surface as they start radiating the energy received during summer. This results in a reversal wind flow from the landmass to the ocean (Bay of Bengal and Indian Ocean). This reversal wind flow is called Retreating South West monsoon.

By November, snowfall in central Asia causes the formation of an anticyclone cell from which cold air moves to Bay of Bengal This air mass enters India through Khaibar pass being influenced by the northeast Trade wind flow. As a result, this air movement from Central Asia to the Indian landmass is called as North East monsoon During winter, the southerly branch of Jet Stream, which rests over Indo-Gangetic plains, gets mixed up with the North East monsoon and brings a cold weather condition throughout India specially the northern part f the sub-continent During this period, a warm and moist airflow moves from west to east known as the 'Western Disturbances'. This airflow originates over the permanent high-pressure cell over Azores Island in the Atlantic Ocean This airflow also enters India through the passes located in northwestern India. In this part of India i.e , J&K, Himanchal Pradesh, Punjab, Haryana, Delhi, Uttaranchal etc , confluence of these three airstreams such as Jet Stream, the North East monsoon and the warm air moving as western disturbances take place which, cause frontal precipitation in the form of snow in J&K, Himachal Pradesh mountains and rainfall in Punjab, Haryana, Delhi etc This period is known as the period of North East monsoon These monsoon winds moving over Bay of Bengal pick up moisture and cause rainfall in Tamilnadu coast This part of India receives rainfall during three different seasons e.g during South West monsoon (small amount), retracting monsoon and North East monsoon

3. Jet Stream

The rising equatorial air through convection currents moves in the upper air as long wave circulation Bands of air currents move in the upper atmosphere from west to east due to the rotational force. This westerly airflow in the upper atmosphere is called Jet Stream, which is intimately related, both to the upper long waves and to the surface weather.

Jet Stream is defined by W M O as a 'strong narrow bands of strong winds concentrated along a quasi-horizontal axis in the upper troposphere and lower stratosphere, characterized by strong vertical and lateral wind shear. Jet Stream is a pat of the upper air circulation which moves invariably from west to east except the easterly tropical jet stream It is a cold and dry air mass, which is uniformly distributed throughout its length, breadth and volume. Their wind speed varies considerably in different longitudes They move faster in winter than summer. The average speed of the jet stream during winter varies between 150 to 200 km per hour Highest speeds occur at altitudes about 30,000′ to 40,000′ The average height of occurrence of the jet is between 20,000 ft to 30,000 ft. It occurs in various latitudes too. They move from west to east

3.1 Types of Jet Stream

i) Sub – Tropical Jets
ii) Westerly or Ferrel's Jet
iii) Circum-Polar Jet (Surface Flow)
iv) Easterly Tropical Jets

4. Influence Over Local Weather

There is a direct relationship between surface weather and jet stream They are responsible for the formation of mid-latitude cyclones It affects the movement of other air masses It brings a cold weather condition in the areas where it is felt During winter, its intensity increases and the surface weather conditions are greatly modified. In India, the effect of jet stream is quite felt during winter. During summer, due to local heating and rising warm air, the jet stream is weakened It brings a cyclonic weather Rainfall, snowfall, thunderstorms, tornadoes, cold waves are all directly affected by the jet streams aloft

CLASSIFICATION OF WORLD CLIMATES

B. S. Mallasamanta

1. Introduction

Geography seeks to understand man and environment relationship Man is the central theme in any study of geography. It seeks to probe into different activities of man like: (i) Where he lives? (ii) What does he do for a living? (iii) How does he interact with the physical, social and economic environments? It could be said that geography is the systematic study of human activities and the factors (natural or man-made), which influence these activities. Out of all the factors, climate is the single most important determinant in the totality of human activities e.g. life style, attitude, settlement, social, cultural, economic etc.

2. Need for Classification

Different parts of the Earth experience different forms of climate with different compositions of elements. There are also regional variations in the amount, intensity and seasonal distribution of the elements, as determined by climatic controls. These variations are mainly due to the spherical shape, vastness in size, rotation and revolution aspects of the Earth.

Similar type of climate is felt in different parts of the world having more or less the same climatic characteristics. Many attempts have been made to identify areas with homogenous climatic parameters and naming them as a certain type based on its characteristics. Attempts are made to divide the earth surface into different homogenous types or to provide a world classification scheme on the basis of homogeneity in certain parameters. Important of them are Thornthwaite, Miller, Supan, Flohn, Strahler, Koppen and Thornthwaite's climatic classification schemes, which are most popular But, due to technical simplicity, Koppen's classification has been widely accepted.

3. Types of Classification

(i) Generic. Classification based on plant growth or vegetation

(ii) Rational, moisture budget classification; based on potential evapo-transpiration based on moisture index

(iii) Genetic. Classification based on genetic distribution of fauna and flora

4. Koppen's Scheme of Climatic Classification

Koppen's climatic classification scheme is a generic based on the relationship between climate and vegetation relied on two major criteria (i) the degree of aridity (ii) warmth Aridity is not simply low precipitation but is expressed in terms of 'Effective Precipitation'

(Precipitation minus Evaporation) In the absence of data on evaporation, temperature is taken as the dummy variable The ratio of rainfall / temperature is used to express the index of precipitation effectiveness on the basis that high temperature increases evaporation The ratio r/f was proposed by R Lang in 1915, where r = mean annual rainfall in mm. T means annual temperature in ^{0}c. So r/t <40 is considered as Arid r/t > 160 is considered per-humid Koppen worked on this principle based on R.Lang's index of precipitation Effectiveness.

Later, he used De Candolle's (French Botanist in 1974) World Vegetation map and published his first classification scheme on the basis of vegetation zones and in 1918 published his final classification scheme in relation to temperature, rainfall and their seasonal characteristics. By using English alphabets he divided the world into six macro climatic divisions.

5. On the Basis of Temperature

A - Tropical rainy climate. coldest month with temperature more than 18^{0}C (64 4^{0}F)

B – Dry Climate

C – Warm temperate rainy climate (Coldest month temperature ranges between – 3^0 C to 18^{0}C and warmest month > 10^{0}C (50^{0}F)

D – Cold Boreal forest climate: (Coldest month < - 3^{0}C (26 6^{0}F) and warmest month >10^{0}C

E – Tundra Climate: (Warmest month 0^{0}C to 10^{0}C)

F – Perpetual frost climate· (Warmest month temperature < 0^{0}C)

6. On the Basis of Rainfall and its Seasonal Characteristics

f = No dry season.

m = Monsoon with a short dry season

s = Summer dry.

w = Winter dry

h = Mean annual temperature > 18^{0}C

k = Mean annual temperature < 18^{0}C

a = Average temperature of warmest month 71 6^0 F and more

b = Temperature of warmest month 50^0 F – 71 6^0 F for 4 months < 50^0 F

c = Temperature of warmest month for 3 months < 50^0 F

d = Average temperature of coldest month < - 36 4^0 F

Combining the effects of temperature, rainfall and their seasonal characteristics Koppen has divided the world into 25 sub-divisions or types of climate They are ,

Af	BSh	Cfa	Csb	Dfa	Dwa	ET
Am	Bsk	Cfb	Cwa	Dfb	Dwb	H
Aw	Bwh	Cfc	Cwb	Dfc	Dwc	EF
	Bwk	Csa		Dfd	Dwd	

The climate type is a combined expression of the climatic parameters such as

Af – Tropical rainy climate (A) with no dry season (f) with temperature more than 10^0 C in the coldest month.

Am– Tropical rainy climate with monsoon type with short dry season with average temperature of coldest month is more than 18^0C

Aw – Tropical rainy climate with dry winter season temperature of coldest month> 18^0C.

Bsh - Dry climate, summer dry with a mean annual temperature of > 18^0C

7. Merits of Koppen's Classification

1) His classification combines temperature and precipitation, two of the most important elements of climate.
2) It accepts native vegetation as the best expression of the totality of a climate so that most of the climatic boundaries coincide with vegetation types
3) His ingenious symbolic nomenclature for the climatic types. The sub-divisions are simple and each letter represents a particular characteristic of climate.
4) Koppen's is a quantitative approach to classification.

1. Introduction

The ocean like the atmosphere that surrounds the earth is dynamic and the waters of the ocean are in a state of constant flux All the different circulations of ocean waters can be regarded in two ways There is a series of horizontal movements of water across the surface of the oceans, but owing to the depth of the oceans, there are also both vertical and horizontal movements across the body of ocean water. The complete circulation is extraordinarily complex and hence can be discussed but briefly in this work Movements of water at any level in the ocean body and in any direction depend upon the differences in density of the water

The density depends upon the temperature and salinity of the water, but movements at the surface also depend upon the major wind flows, which are controlled by atmospheric pressure distributions As the winds move across the water, huge masses of water are pushed along and large amounts of energy are imparted to them While wages and surface currently are primarily produced by the surface currents move as a result of density differences due to thermohaline effects. In addition, the water bodies are subject to tidal motions that are just as regular and pulsating as the general circulatory patterns

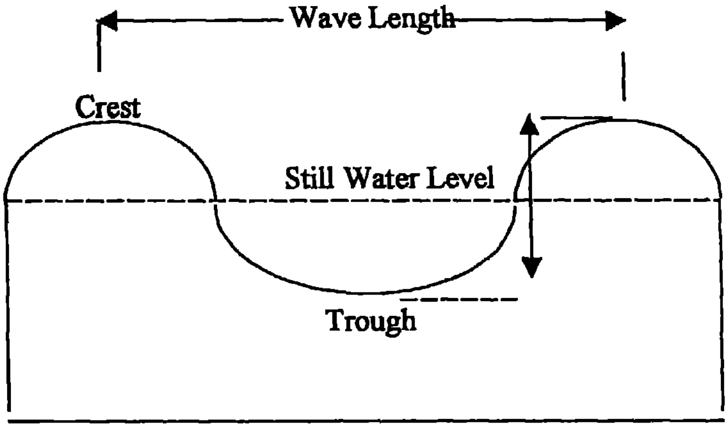
2. Ocean Waves

The surface of the ocean is set in motion by the action of the wind that blows across it Waves are formed on the sea surface as a result of transfer of energy by the moving air to the water below it All most all ocean waves that can be seen and felt are produced by the pressure and friction of the wind on the water surface In the open sea, waves may be regarded as oscillatory movements of the water parties in that the surface of the water body is deformed into troughs and crests

Waves are energy in motion, though the medium (water) appears to be moving up the shores and coastlines in a graceful fashion only to crash onto the continents as the wave breaks. However, the medium actually does not ravel It is the energy that travels and passes through the medium The particles in the medium oscillate and cycle in a back and forth or up and down in orbital motion transmitting the energy from one particle to another

2.1 Wave Anatomy

Ocean waves have distinct parts. The highest part of the wave above the water level is called the crest while the valley between wave crests below average water level is called the trough. The vertical distance between the crest and the trough is the wave height or amplitude usually stated in feet or meters The wavelength is the horizontal distance between adjacent crests or adjacent troughs, also stated in feet or meters The wave velocity is equal to the distance traveled by the wave in seconds given in feet or meters per second The time between passages of two successive crests is called the wave period and frequency is the number of waves passing a fixed point per second.



Anatomy of Waves

2.2 Wave Motion

The seawater in a wave simply rises and falls with a slight to-and-fro motion of rhythmic character, but it does not move ahead unless winds help in the forward movement of the water in the form of current Wind-generated ocean waves belong to a type known as progressive oscillatory waves, because the waveform travels through the water and makes an oscillatory water motion. In the progressive oscillatory wave, a tiny particle, such as a drop of water or a small floating object, completes one vertical circle, or orbit, with the passage of each wavelength The motion of the particle in a wave is forward at the crest and backward in the trough. At the middle of the hinder slope, the movement is downward and at the front slope it is upward. At the sea surface, the orbit is of the same diameter as the wave height, but dies out rapidly with depth. In the long, low waves, the water particles return to the same starting point at the completion of each orbit In steep, high waves, however, the orbits are not perfect circles The particles move just a bit faster forward when on the crest than when it returns in the trough, so that at the end of each circuit the particle has made a slight advance in the direction of the prevailing wind

When the wave moves towards the shore on a gently sloping bottom, it becomes shorter and higher and develops an over steep crescent shaped front Since the motion in the lower part is retarded, the upper part rushes over it forward and downward forming surf. The zone in which surf forms is called breaker zone and the advancing waves near the coast are called breakers After moving up a sloping shore, the water returns seaward as an under current called undertow.

Three factors control the maximum height to which wind waves can grow. First, wind velocity is obviously a major factor; this determines the amount of energy that can be supplied. Second, duration of the wind determines whether or not the waves have an opportunity to grow to maximum size Third, the fetch, or expanse of open water available, is important because the waves travel as they grow If waves are developed in a very large body of water over a period of many hours, so that neither duration nor fetch are limiting factors, the maximum wave height varies as the square of the wind velocity. The wave height, thus, depends on the energy of the wind and is independent of the wavelength. However, the height of a wave cannot exceed $^1/_7$th of its length without becoming unstable and breaking

3. Wave Types

On the basis of their origin, the waves are mainly of four types ; (i) wind wave (ii) tidal wave (iii) seismic wave and (iv) storm waves.

3.1 Wind Wave

It is evident that the surface waves are mostly created by winds Wind waves grow through two mechanisms First, the direct push of the wind upon the windward slope of the wave drives it forward, just as with any sloping object or sail Second, the skin drag of air flowing over water surface exerts a pull in the direction of the wave motion Over the wave crest, where the drag is strongest, the orbital movement is supplemented, adding energy to the wave. In the trough, which is protected, drag is weaker, hence does not counteract the reverse orbital movement as forcefully as it is assisted on the crests The result is a steady increase in wave height and length, to some maximum point possible under a given 8 wind strength As waves continue to grow, they not only increase their speed of travel, but become longer as well When they have passed beyond the region of strong winds that formed them, waves are transformed into a swell, consisting of very long, low waves of simple form and parallel, eve crests.

3.2 Tidal Waves

The occasional high waves causing enormous damage to the invaded area are often designated as 'tidal waves', but their origin is not related to the tide generating forces. Other agencies connected with the internal structure of the earth or the atmosphere are actually responsible for them.

3.3 Seismic Waves

These waves owe their existence to the sea earthquakes and volcanic eruptions. Once formed, they attain tremendous dimensions of great force and fury and are also called as Tsunami (Japanese). These waves rise to a height of 15 meters in many cases and well over 30 meters in rare instances. History provides many examples of such seismic waves, which have caused appalling loss of life. Sometimes, these tidal waves caused by the earthquakes travel thousands of kilometers and affect the coastal areas of distant countries

3.4 Storm Wave

The waves caused by storms, hurricanes and strong winds are elements of destruction and havoc on the coastal lands. This is mainly due to rise of general water level and the force of wind that the wave derived from the disturbances. One such storm wave was responsible for 300000 casualties on 7th Oct 1937 in the Bay of Bengal.

Niranjan Dash

1. Introduction

A tide is the periodic elevation and depression of the of the sea surface in response to the pull of the moon and more distant sun Its character is complicated due to changing positions of the attracting bodies. Though both the sun and moon exert tide forces upon the earth, it is the moon, by reason of its closeness, controls the timing of the tidal rise and fall of the ocean level The moon bas a tide producing power more than twice of the sun. There would be a pair of high tides and a pair of low tides at any one time if the earth had a uniform cover of water. Two high tides are formed at the same time on opposite sides of the earth and so is the case of two low tides The rising tide is known as flood tide and the falling tide is called ebb tide.

2. Formation

Sir Isaac Newton propounded a rational explanation of tides and tide producing forces for the first time in 1687 His theory of equilibrium was based on the universal law of gravitation This law states that any two objects attract each other with a force that is directly proportional to the product of their mass and inversely proportional to the square of the distance between them. Essentially this law tells that as the earth causes the moon to revolve around the earth, the moon also exerts an effective pull on the mass of the earth Based on the above diagram, the gravitational pull of the moon is maximum at 'A' because it is closest At 'C', the earth center, the attraction is less than at 'A' ad at 'B' it is least of all. Because from 'A' through 'C' to B, there is a tendency of the earth to be pulled apart While the ocean water at A tries to pull away from the main mass of the earth, centered at 'C', the main body of the earth tends to pull away from the ocean water at 'B' Thus, the water at 'B' having the least attraction is left behind and a bulge is created there

Later the above explanation was modified and said that earth and moon act as a single system and revolve around a common center of gravity i e. barycenter for both masses. In the earth-moon system, the barycenter lies about 2900 miles (4800 kms) from the center of the earth. As the moon moves around the barycenter, its gravitational force causes the waters of the earth to bulge onward on the side of the earth facing the moon At the opposite side of the earth, centrifugal forces produced by the earth's rotation causes second, slightly lower bulge of

water to be thrown outward Thus, the earth has two bulges or high tides, which appear on a straight line with the moon and two through or low tides, which appear between the highs at right angles to the moon As the moon moves around the barycenter, the bulge of water follows beneath it, bringing all parts of the earth into contact with the highs and lows alternate period

3. Distribution of Tide Producing Forces

The tide producing forces vary according to the changing positions of the celestial bodies in relation to one another Therefore, the time of tide and the tidal elevations at any place on the earth's surface vary accordingly During the passage of a single year, the moon changes its position from 28 5^{0N} latitude to 28 50S latitude. This change in the moon's position over the earth causes the bulge to shift with the moon Thus, tides in a single year are not the same through out the year. The tides do not pass around the earth at precisely the same time each day through out the year due to shifts in the moon's passage around the earth The moon passes over each locality about 50 minutes later each successive day Thus, tides occur 50 minutes later than the day before.

In addition tides do not coincide exactly with the moon's position as it passes each given point on the earth surface Due to the friction between the earth and the tidal bulge, the tide occurs, on an average, 59 minutes after the moon's passage. However, this factor is apparent only in the delay in the daily tide. One other major factor that influences the height of the tidal bulge, is the gravitational zone of the sun. the various positions of the sun in relation to the moon and earth results in tides of different magnitudes. When the centers of the sun, moon and earth results in tides of different magnitudes. When the centers of the sun, moon and earth are almost in a line (moon in Sy Zy Zy) – the case at full moon and at new moon, the forces act in a combined manner to produce high or spring tides When the lines joining the center of the three bodies are almost at right angles to each other (moon in quardrature), the forces act opposite to each other and produce neap tides

The orbits of celestial bodes are also responsible for varying height of tides The moon follows the elliptical orbit round the earth and, therefore, higher than normal tides, is produced when she is nearest to the earth (Perigee) When farthest from the earth (Apogee), the tide force is below normal The tides are 20% above the average in perigee and 20% below the average in apogee. Similarly, slightly higher tides are produced in perihelion position than in aphelion position.

4. **Types of Tides**

The response of the bodies of water to the tide producing forces of moon and sun is affected by rotation and declination of the moon and the sun, which determines the nature and, type of tides While the former produces daily forces completing circle in one day resulting in daily tides, the latter creates semi-diurnal forces active in a complete circle in half a day. The main types of tides, thus, produced are the following.

(i)	Semi-Diurnal tides	·	Recur at intervals of 12 ½ hours.
(ii)	Diurnal tides	.	Recur at intervals of 24 ¾ hours
(iii)	Spring tide	:	Recur once a fortnight due to the revolution and declination of the moon
(iv)	Neap tides	.	Recur once a fortnight due the revolution and declination of the moon.
(v)	Monthly tides	.	Due to the revolution of the moon and its positions at Perigee and Apogee.
(vi)	Equinoctial Spring tide	.	Recur at an interval of six months due to the revolution of the tide Earth round the sun and sun's varying declination. (When the sun is at the equinoxes with zero declination, along with moon with zero declination.
(vii)	Yearly tides		Due to revolution of the earth and the position at Perihelion and Aphelion

OCEAN CURRENTS

Niranjan Dash

1. Introduction

The ocean current is the general horizontal movement of a mass of water in a fairly defined direction under the various forces, internal as well as external These surface movements can be differentiated on the basis of the speed of travel into currents, drifts and streams. The currents are readily observed, as they have speeds of 1-5 knots and are of importance to navigation, the drifts are slow, almost imperceptible, movements of large masses of water with a large surface area. The narrower and swifter movements are called streams

2. Factors Controlling the Currents

A host of factors are at work in explaining the phenomena of currents and their distinct regional pattern. Chief among them are ,

(i) Factors in relation to earth's nature

a). Gravitational Force, b) Deflective force due to earth's rotation

(ii) Ex-oceanic factors

a). Atmospheric pressure variations b). Wind and the frictional force

c). Precipitation d). Nature of evaporation and isolation

(iii) Sub-oceanic causes

a). Temperature difference b) Salinity

c). Density d) Melting of Ice

(iv) Factors modifying ocean currents

a) Direction and shape of the coastline b) Seasonal variations

c) Bottom Topography

2.1 Factors in Relation to Earth's Nature

The gravitational force and the deflection due to earth's rotation are the factors in this category

(a) Gravitational Force: It is a well known fact that any particle on or near the earth's surface is attracted towards the center of the earth due to the force of gravity. Thus, any particle of the ocean mass is also subjected to pure gravitational force directed towards the central region of the earth This force varies with latitude and distance from the center of the earth As the polar diameter is lesser than the equatorial diameter, this force is greater at the poles Generally, the

gravity increases pole ward Similarly, deeper places in the ocean are nearer to the center, hence gravitational force varies Thus, the resultant effect on the currents would be a pull directed towards the center

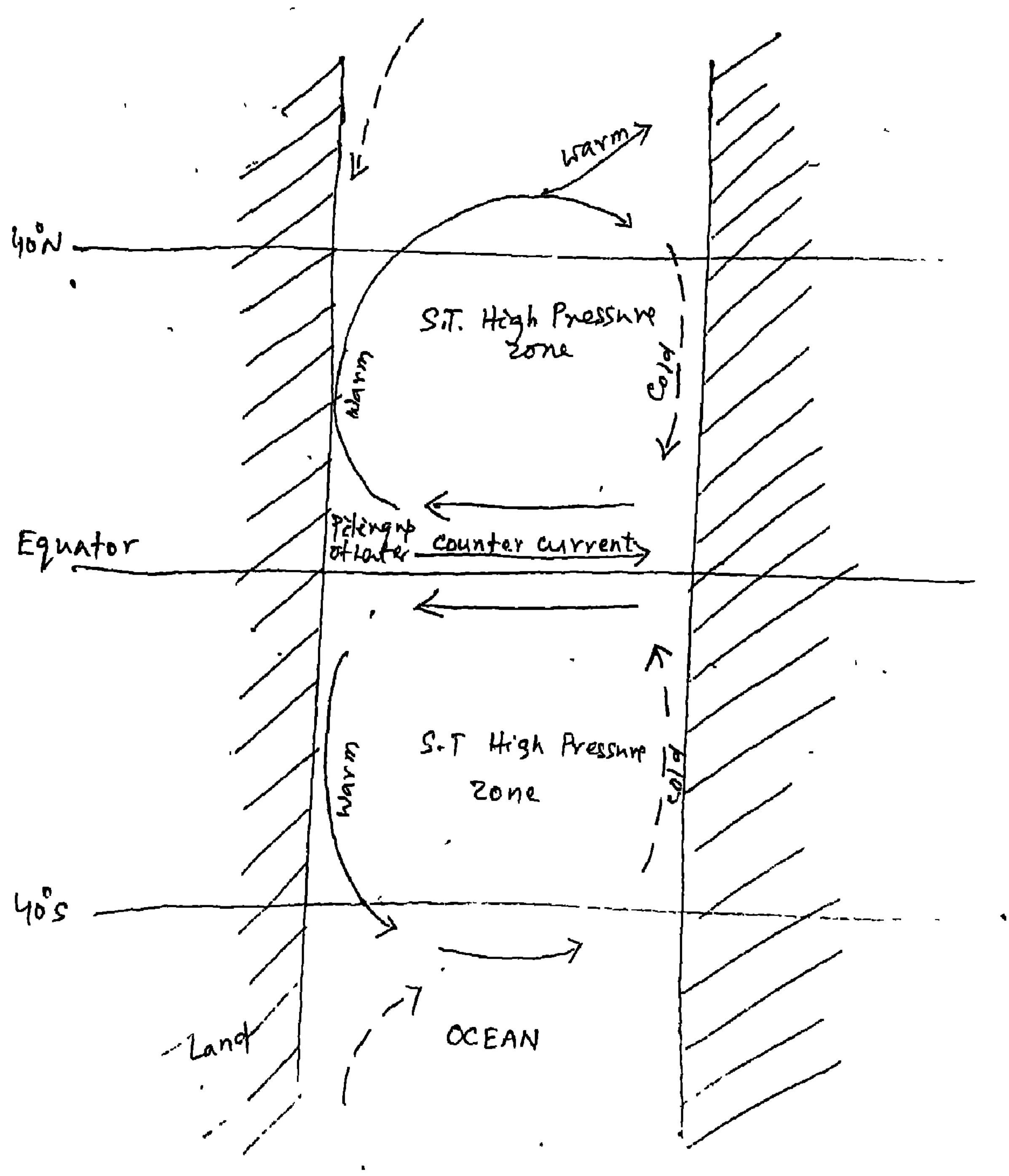
(b)Deflection due to Earth's Rotation: The rotation of the earth results in deflective or coriolis force which has a tendency to throw away particles from the center of the earth, opposing to the gravitational pull. Though small in magnitude, this force acts as an important controlling factor of currents Under the effect of this force, the moving water turns to the right in the northern hemisphere and to the left in the southern hemisphere Thus water moving from equator to midlatitudes will have southwest direction in the northern hemisphere and north-west direction in the southern hemisphere On the other hand, the water moving from the poles towards the equator will have north-west and south-east direction respectively in the northern and southern hemisphere

2.2 Ex-Oceanic Factors

(ii) **Atmospheric Pressure and its Variations:** Atmospheric pressure is of primary significance in the fundamental equation of motion Over regions of greater atmospheric pressure, the level of the sea is found to be lowered and vice versa The result of the two situations on the currents is that a surface current moves outward from the areas attaining higher sea level (or low atmospheric pressure) towards that of the lower level.

(iii) **Wind and Frictional Forces:** Virtually all of the important surface currents are set in motion by prevailing winds Energy is transferred from the wind to water by the frictional drag of the air blowing over the water surface. Under the influence of the trade winds, water of the oceans move from east to west in the form of equatorial currents and similarly the westeries force the water to move from west to east in the mid-latitude region A constant and perennial wind blowing in one direction may tend to bank up the water close to the coast of a continent, in which case the force of gravity, tending to equalize the water level, will cause other currents to set up

(iv) **Precipitation :** Excess precipitation on oceans disturbs the level and results in the slope currents to equalize it High rainfall in equatorial regions not only raises the sea level, but also decreases the salinity and density urging the water to flow northwards and southwards from equator.



Generalised Surface Circulation in an Ocean.

(v) **Nature of Evaporation and Insolation :** Differences in the distribution of insolation and amount of evaporation over the oceans leads to current formation. High insolation and less evaporation keep the surface water lighter and les dense as compared to water surface with high insolation and high evaporation Where the density is increased This variation in density leads to surface movements to comparatively denser areas

2.3 Sub – Oceanic Causes

(i) **Temperature Differences:** Variations in the receipt of solar energy, cause temperature differences in the seawater. The higher temperature in a region means greater expansion of water particles The water having higher temperature would expand or move towards colder areas on the surface. As the low latitude regional are hotter than high latitude region, there is movement of surface water from the equator towards poles and the cold water at the poles sinks and moves towards the equator as a sub-surface current

(ii) **Salinity:** Salinity difference is also responsible for generation of currents in seawater. Waters of higher salinity are denser as compared to the less saline waters. This causes the water level to sink at high salinity regions resulting a flow of water from low salinity parts of the sea Such currents are most pronounced in straits joining the enclosed seas with the oceans

(iii) **Density:** Density is a function of temperature, pressure and salinity and directly controls the current The low-density water being lighter expands and flows as a surface current towards highly dense water regions, and a sub-surface current of higher density flows from regions of greater density to lesser density.

(iv) **Melting of Ice:** Due to ice melting, the sea level rises and the salinity of water decreases. Hence the currents move outwards from such regions The East Greenland current is supposed to be a current of this nature

2.4 Factors Modifying Ocean Currents

(i) Direction and shape of the coastline: Configuration of the coastline also has controlling influence on the water movements Currents initially controlled by winds impinge upon a coast and are locally deflected to a different path or confined in straits or gulfs The bifurcation of the south equatorial current in Atlantic Ocean at Cape Sao Roque provides best example of such effect.

(ii) Seasonal Variations: Seasonal variations in direction and in the volume of the currents are found in specific areas of wind shift belt or in special climatic regions The currents of the Indian Ocean show a marked change in their direction

(iii) Bottom Topography: The configuration of the ocean basins to some extent modifies the surface as well as sub-surface currents This is particularly true of middle and high latitude as where the currents tend to follow the bottom contours.

3. Generalized Scheme of Ocean Currents

The Atlantic, Indian and Pacific Oceans are sufficiently extensive from north to south to have surface circulations, which may be shown by a generalized diagram for one ocean. The most significant features of this pattern of currents are the circular movements or gyres around the subtropical highs, centered about 25° to 30° N and S These two circulations approach one another in equatorial latitudes, so that westward flowing currents are found immediately north and south of an eastward flowing counter current. The equatorial currents are deflected pole ward by the continental margins on the western side of the oceans. Eventually, when they come under the influence of the westerly, they become eastward-moving currents In part, at least, these eastward currents are deflected towards the equator on the eastern side of the oceans.

In high latitudes, there are currents, which move in an equator ward direction and are of polar origin. They move westward under the influences of polar easterlies and enter warm latitudes on the eastern side of the continents. Thus, two gyres are formed in the northern and southern part of the oceans. In the central portion, through minor eddies develop; yet there is no marked development of the current

PRINCIPLES OF REGIONALISATION WITH SPECIAL REFERENCE TO INDIA

P. K Das

1. Concept of Region

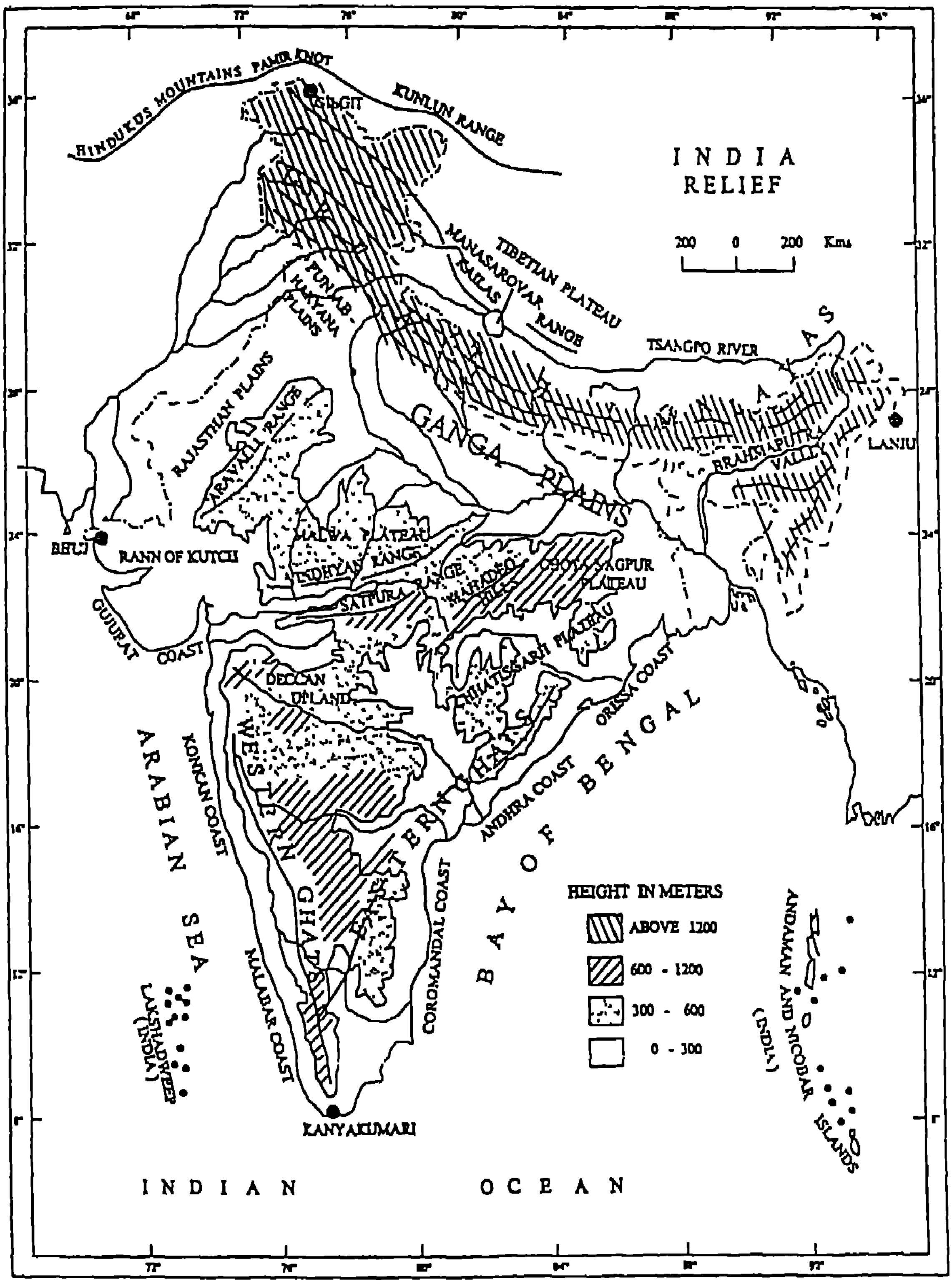
Region is the concrete connotation of a unit of space. Space in the context of geographical study implies surface of the earth in general. A region stands for a unit of space with a definite boundary Hence a region portrays certain distinct characteristics of its own which projects that spatial unit as unique. It is unique in the sense that within its boundary some kind of homogeneity, such as relief, climate, natural vegetation, socio-cultural feature like language, race etc. prevails At the same time this unit becomes different from its neighboring units on the basis of the same criteria, i e heterogeneous with respect to its neighbors Every scheme of ragionalization meets a particular objective As for example, when a country is divided into states or provinces the result is political or administrative regionalization Normally, a social or cultural attribute like language, race etc is taken into account in order to arrive at political regionalization. Similarly when we attempt at economic regionalization spatial variability of some economic parameter/parameters is taken into account. Thus, every scheme of regionalization has its own identity meeting a specific purpose. First stage of regional division of a country or continent results in first order divisions or macro regions Subsequently, when each first order division or macro region is further subdivided by chosing a parameter other than the one that had been taken for the purpose of first order divisions, second order divisions or meso regions emerge

2. Basis of Regionalization

As far as scheme of natural regions is concerned, it is essentially a scheme of geographically regions In this scheme a suitable natural parameter, not social or cultural parameter, is taken into account in order to divide a country or continent into minimum number of divisions The parameter may be relief or soil or geology or natural vegetation or a climatic element etc

3. The Regions

In case of India (excluding the islands) 'Relief' divides the country into minimum number of 1st order natural regions, i e four The divisions are (i) The Northern Mountains, (ii) The Great Plains, (iii) The Peninsular Uplands and (iv) The Coastal Plains

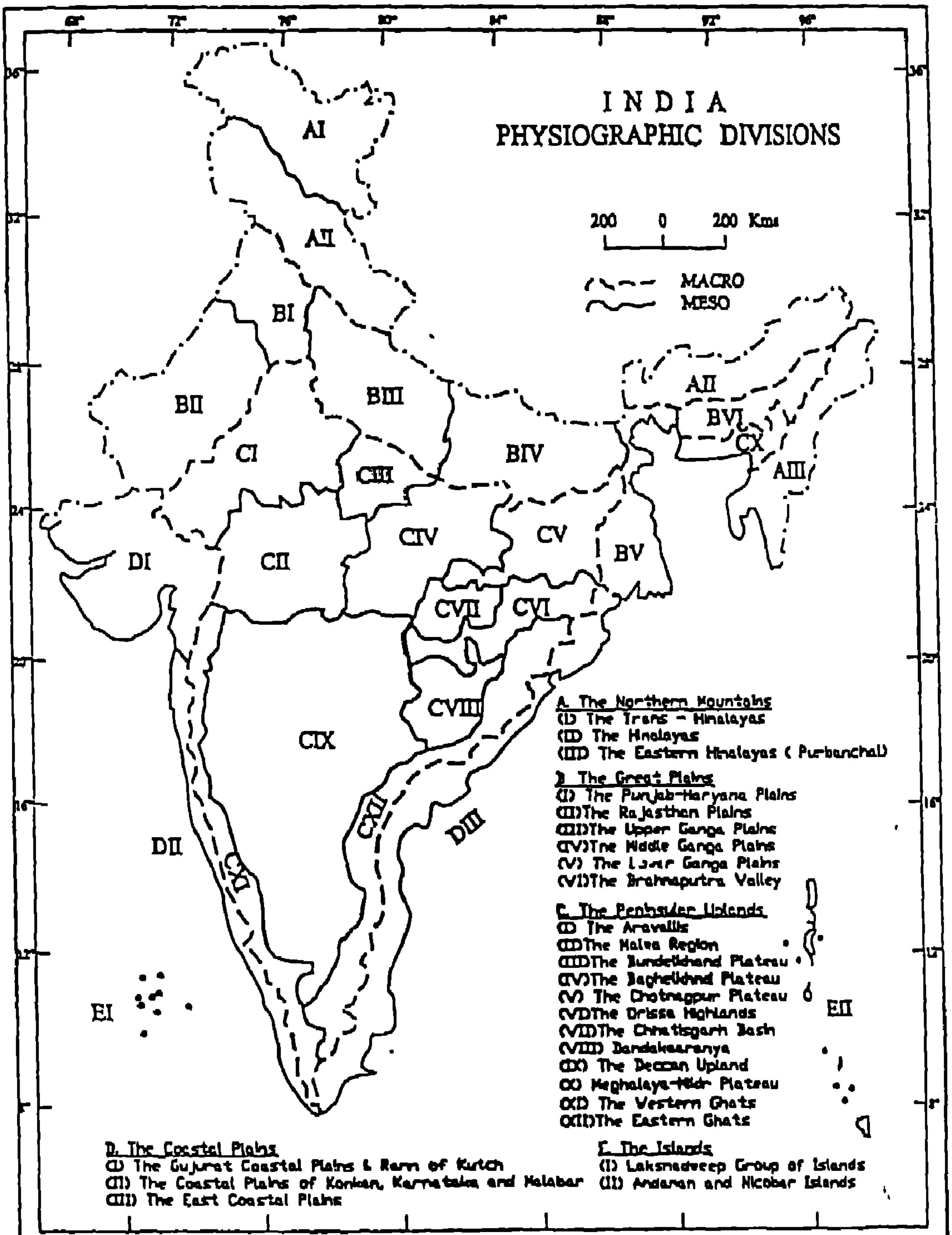

INDIA
RELIEF
200 0 200 Kms
HINDUKUS MOUNTAINS
PAMIR KNOT
GILGIT
KUNLUN RANGE
TIBETIAN PLATEAU
MANASAROVAR
KAILAS
RANGE
PUNJAB
HARYANA
PLAINS
TSANGPO RIVER
RAJASTHAN PLAINS
ARAVALLI RANGE
GANGA
PLAINS
BRAHMAPUTRA
VALLEY
LANJU
BHUJ
RANN OF KUTCH
MALWA PLATEAU
VINDHYAN RANGE
SATPURA RANGE
MAHADEO HILLS
CHOTA NAGPUR
PLATEAU
CHHATISGARH PLATEAU
GUJURAT COAST
DECCAN
UPLAND
WESTERN GHATS
EASTERN GHATS
ORISSA COAST
ANDHRA COAST
ARABIAN SEA
KONKAN COAST
MALABAR COAST
COROMANDAL COAST
BAY OF BENGAL
HEIGHT IN METERS
ABOVE 1200
600 - 1200
300 - 600
0 - 300
LAKSHADWEEP
(INDIA)
ANDAMAN AND NICOBAR
ISLANDS
(INDIA)
KANYAKUMARI
INDIAN OCEAN

"Northern Mountains" based on spatial variation of climatic elements, i e. temperature and precipitation is divided into (i) Trans-Himalayas, (ii) The Himalayas, (iii) the Eastern Himalayas (Purbanchal) as 2nd order or Meso regions

"The Great Plains" on the basis of spatial variation of alluvial deposits and soil is divided into (i) the Punjab-Haryana Plains, (ii) The Upper Ganges Plains, (iii) The Middle Ganges Plains (iv) The lower Ganges Plains and (v) The Brahmaputra valley as the 2nd order divisions or meso regions.

"The Peninsular Uplands" on the basis of minor relief like river basin, water divide, plateau etc. is divided into (i) The Aravallis, (ii) The Malwa Region (iii) The Bundelkhand Plateau, (iv) The Baghelkhand Plateau (v) The Chotnagpur Plateau (vi) The Orissa highlands (vii) The Chhatisgarh Basin, (viii) Dandakaranya Plateau (ix) The Deccan Upland (x) Meghalaya-Mikir Plateau (xi) The Western Ghats (xii) The Eastern Ghats as 2nd order divisions on meso regions.

"The Coastal Plains" on the basis of location and morphological variation is divided into (i) The Gujarat Coastal Plains and Rann of Kutch (ii) The Coastal Plains of Konkani, Karnataka and Malabar (iii) The East Coastal Plains. This scheme of natural regions of India is clearly portrayed in the given maps.



Source : INDIA - A Regional Geography (Ed. R. L. Singh)

B. S Mallasamanta

1. Introduction

Natural regions of the are mainly characterized by climatic variables. A uniform climatic condition prevails in a natural region for which a region gets identified with its climatic type. In any geographic space, its vegetation, soils, methods of house building, clothing of the people, attitude of the people are influenced by its climate There are many climatic regions with similar type of climate, which could be grouped as a single natural region A J. Herbertson started this concept of natural region in 1905 Studying the variation of its natural vegetation does the division of the earth surface into different natural regions, as vegetation is the replica of climate Some have divided the world on the basis of air mass source region. Koppen has adopted the first method in dividing the world into climatic regions On the basis of the classification based on air mass source region, the earth surface is divided into four natural regions by Herbertson :

(i) Low latitude natural regions

(ii) Middle latitude mountainous region

(iii) High latitude natural regions

(iv) High mountainous natural regions

These four latitudinal natural regions are further sub-divided into the following natural regions.

1.1 Low Latitude Regions

(i) Equatorial Region - Amazon, Congo, Guinea, South Srilanka, Malaysia, Indonesia.

(ii) Monsoon Region - Asia

(iii) Tropical Grasslands - Savanna

(iv) Hot deserts - Sahara, Australia, Kalahari

1.2 Middle Latitude Regions

(i) Mediterranean

(ii) Temperate Desert Region

(iii) Mid-latitude East Coast Climate (China type)

(iv) Middle East Temperate Region (Manchuria type)

(v) Temperate Grassland (Steppe)

(vi) Western Coastal Cool Temperate Region (British type)

1.3 High Latitude Regions

(i) Cold Temperate Regions (Taiga)

(ii) Polar Regions or Tundra

1.4 High Mountainous Regions

1. Topographical Maps

The most important tools available for laboratory study of landforms are topographic maps and air photographs. The student of geomorphology must be able to read and interpret topographic maps quickly and accurately, translating the characteristic forms he sees on maps into verbal statements covering classifications, descriptions, and evolutionary aspects of each.

Several methods have been used to show accurately the configuration of the land surface on topographic maps. Methods described below are plastic shading, altitude tints, hachure, and contours. The first three processes give a strong visual effect of three dimensions so that even untutored persons can grasp the essential character of the landscape features without preliminary explanation. But, as compensation for ease of understanding, such methods of showing relief are inadequate because they do not tell the reader the elevation above sea level of all points on the map, or how steep the slopes are The method of topographic contours, however, gives this information and makes the most useful type of topographic map

2. Contours

A contour may be defined as an imaginary line on the ground, every point of which is at the same altitude, or elevation, above sea level. Contour lines on a map are simply the graphic representations of ground contours, drawn for each of a series of specified elevations such as 10, 20, 30, 40 or 50 ft or meters above sea level or any other chosen base, known as datum plane The resulting line pattern not only gives a visual impression of topography to the experienced student of maps but also supplies accurate information about true elevations and slopes

In order to clarify the contour principle, various commonplace things can be used for illustration Imagine, for example, a small island The shoreline is a natural contour line because it is a line connecting all points having zero elevation. Suppose that sea level could be made to rise exactly 10 ft (or that the island could be made to sink exactly 10 ft.) ; the water would come to rest along the line labeled "10" This would be the 10-ft contour because it connects all points on the island that are exactly 10 ft higher than the original shoreline By successive rises in water level, each exactly 10 ft more than the last, the positions of the remaining contours would be fixed. Although contours are almost never obtained in this way, a very similar procedure was followed in the mapping of some parts of the valley that Lake Mead occupies behind Boulder Dam As the lake level slowly rose, air photographs were taken. With

each rise of 2 ft (0.6 m) in lake level, the successive shorelines accurately showed positions of the contours

3. Contour Interval

Contour interval is the vertical distance separating successive contours The interval remains constant over the entire map, except in special cases where two or more intervals are used on the map sheet It is essential then that full information be present on the map margin, describing the areas in which each interval is used

Because the vertical contour interval is fixed, horizontal spacing of contours on a given map varies with changes in land slope The general rule is close crowding of contour lines represents a steep slope; wide spacing represents a gentle slope An island, as given here shows one side of which is a steep, cliff like slope. From the summit point B to the cliff base at A, the contours are crossed within a short horizontal distance and therefore appear closely spaced on the map From B to the shore at C the same total vertical descent is made, but because the slope is gentle, the horizontal distance is much greater Hence, the contours between B and C are widely spaced on the map

Selection of contour interval depends both on reliefs of the land and on scale of the map Topographic maps showing regions of strong relief require a large interval, such as 50, 100, or 200 ft (15, 30, or 60 m) ; regions of moderate relief, intervals such as 10, 20, 25 ft (2, 5, or 10 m) In flat country, and interval of 5 ft (1 m) or less may be required Large intervals are used on small-scale maps both because a greater range of elevations is likely to be included and because there is a limit to how closely contours can be printed without fusing into a dense mass.

Because streams flowing in valleys sculpture by far the greatest parts of the earth's land surfaces, special note should be made of how contours behave when crossing a stream valley (Fig 6) is a small contour sketch map illustrating some stream valleys Notice that each contour is bet into a 'V' whose apex lies on the stream and points in an upstream direction The reason for this deflection is that the contour must maintain the same elevation, hence must follow the valley side upstream to a point where the stream gradient brings the steam to the same elevation as the contour On most topographic maps only the larger streams are actually shown by any line, but the positions of numerous small channels can be deduced from V indentations of the contours

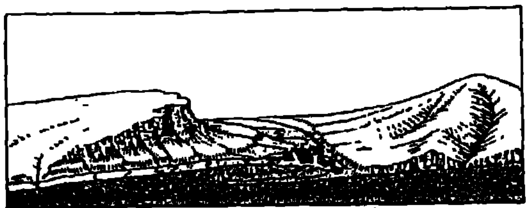


Fig-1 Terrain Sketch

Fig 2. Hachures

Fig 3 Contours

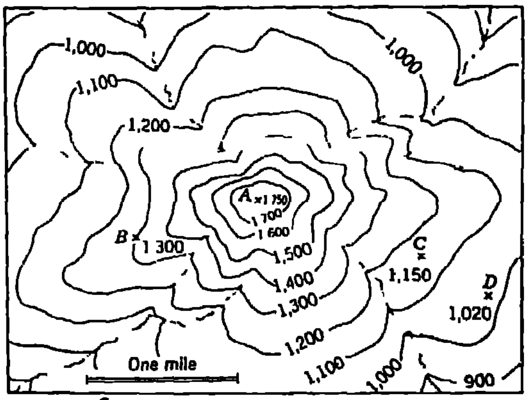


Figure 6 Stream valleys produce V-shaped indentations of the contours.

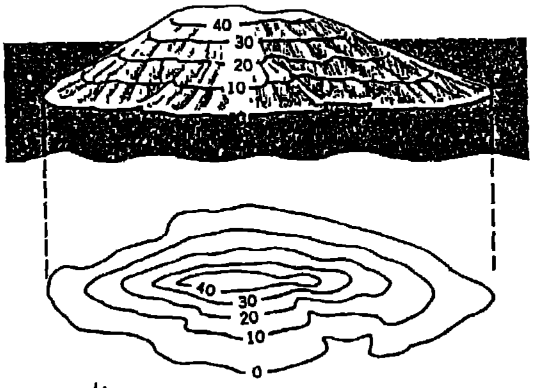


Figure 4 Contours on a small island

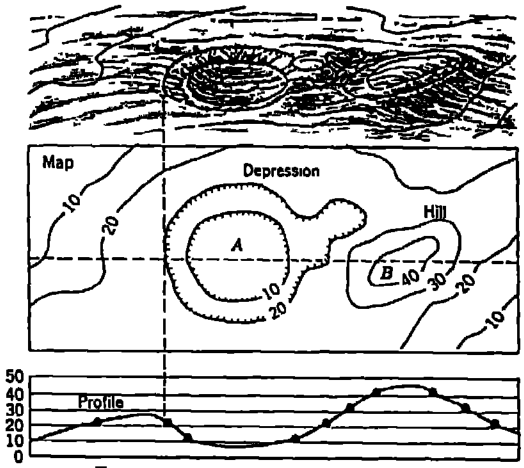


Figure 7 Contours which close in a circular manner show either closed depressions or hills.

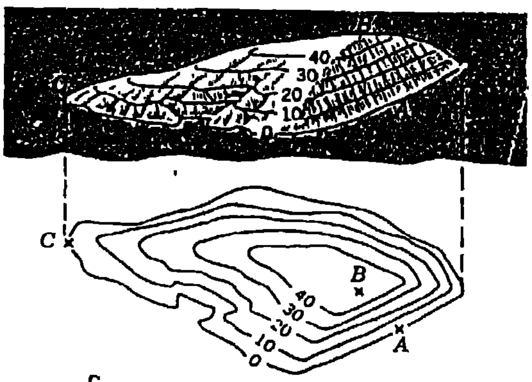


Figure 5 On the steep side of this island the contours appear more closely spaced.

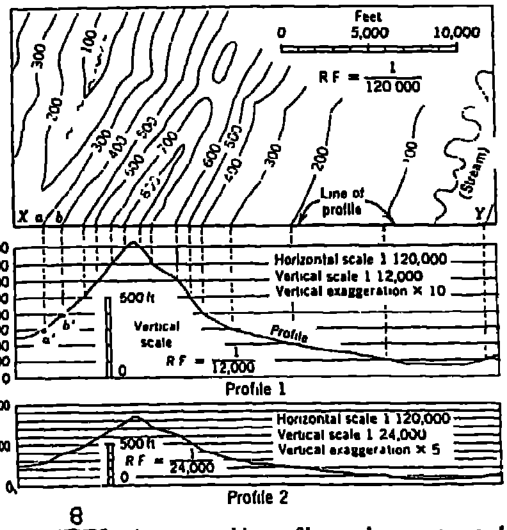


Figure 8 A topographic profile can be constructed from a contour map along any desired line.

4. Determining Elevations by Means of Contours

Although each contour stands for a certain precise elevation, it is not practical to number all the lines, or to place the numbers so close together as to be always close at hand. A common practice is to make every fifth contour line much heavier than the rest, and to number the heavy lines at frequent intervals. This not only makes it easier to grasp essential features of the topography but also facilities finding the elevation numbers

Figure 6 can be used to illustrate the determination of elevations. Point B is easy to determine because it lies exactly on the 1300-ft contour. Point C requires interpolation Because ıt lies midway between the 1100- and 1200-ftlines, its elevation is likewise the mid value of the vertical interval, or 1150 ft. Point D lies about one-fifth of the distance from the 1000 to the 1100-ft contours Because one-fifth of the contour interval is 20ft For the last two points only a guess has been made as to the true elevation, but if the ground is not too irregular the error will probably be small. Determination of the summit elevations, point A, involves still more uncertainty. It is certain that the summit point is more than 1700 ft and less than 1800 because the 1700-ft contour is the highest one shown Because a sizable area is included withın the 1700-ft contour, it may be supposed that the summit rises appreciably higher than 1700 A guess would place the true elevation at about 1750ft.

On many topographic maps the elevation of hilltops, road intersections, bridges, lakes, and so forth, is printed on the map to the nearest foot or meter These spot heıghts do away with the need for estimating elevations at key points

5. Topographic Profiles

In order to get better ideas of the nature of the relief, topographic profiles are sometimes drawn These are lines that show the rise and fall of the land surface along a selected line crossıng the map Figure A1.20 illustrates the construction of a profile A line, XY, is lightly drawn across the map at the desired location A piece of paper, ruled wıth horizontal lines, ıs placed so that its top edge lies along the line XY Each horizontal line represents a contour level and is so numbered along the left-hand sıde Starting at the left, a perpendicular is dropped from the point a where the map contour intersects the profile line, XY, down to the corresponding horizontal level A point a is marked on the horizontal line Next, the procedure is repeated for the 400-ft contour at point b, and so on, until all points have been plotted A

smooth line is then drawn through all the points, completing the profile. Where contours are widely spaced, some judgment is required in drawing of the profile

Figure 8 shows two profiles, both of which are drawn along the same line XY The difference ıs one of degree of exaggeration of the vertical scale In this illustration, horizontal map scale is 1 in. to 10,000 ft, or 1.20,000, whereas the vertical scale of the upper profile is 1 in. to 1000 ft, or 1:12,000. The vertical scale is thus tem times as large as the horizontal map scale, and the profile is said to have a vertical exaggeration of ten times. In the lower profile, the horizontal scale remains the same, of course, but the vertical scale is 1 in to 2000 ft, or 1.24,000 The vertical exaggeration is therefore five times. Some degree of vertical exaggeration is usually needed to bring out the nature of the topography A natural scale profile, one in which the vertical and horizontal scales are the same, would give a profile with such tiny fluctuations as to be not only difficult to read but also difficult to draw or reproduce The human eye exaggerates the height of topographic features and the steepness of slopes when they are seen from ground level. For this reason, a moderate degree of profile exaggeration should be avoided. In Figure 8 the upper profile is excessively exaggerated, but the lower one is more suitable for general purposes

Topographic profiles are used in highway and railroad planning to estimate the degree of cutting or filling needed to establish a smooth grade. In military operations, profiles are required to determine the limits of visibility from key observation points

FIELD STUDY REPORT ON GEOMORPHOLOGICAL PROCESSES AND ENVIRONMENTAL DEGRADATION OF CHILIKA LAKE *

1. Introduction

The problem of environmental degradation and ecological disturbances of the wetlands has been major issue for their special ecological features and biodiversity. The wetlands are the marshes or shallow water marginal areas of large water bodies in the seral stages of succession from open water to dry land or vice versa.

The Chilika is the largest brackish water lagoon of Asia situated along the eastern shore of peninsular India. But the first deteriorating environmental conditions of this lagoon have been a conspicuous feature The important factors for the deterioration of the lagoon are shifting of the mouth and reduction of its width, siltation in the lagoon, nutrient enrichment and luxuriant growth of the aquatic weeds, erosion in the catchments and reclamation by the inhabitants. Besides all these factors of environmental degradation of the lagoon, there are also some natural factors and geomorphic process of the shore, catchments and the lagoon itself which sets-in and activate the processes of environmental degradation The present report is an out come of a field work under taken by the trainees in understanding the environmental and geomorphic processes affecting the degradation of the lagoon and eco-restoration of the wetland.

Chilika with an area of 1050 sq km is situated to the southeastern part of the Eastern ghats of Orissa. It is located between 19° 28'N to 19° 55'N and 85° 06'N to 85° 35'E. It swells to 1165 sq km in the rainy season and reduced to 906 sq.km. in the summer season. The lake is circumscribed by a 60km. stretch of coastal barrier bar of the Bay of Bengal along the eastern margin, rocky hills and spurs of the Eastern Ghats along the western and southern margin and the deltaic plains of the Mahanadi system in the northern margin The lake is connected with the Bay of Bengal through an outlet near Arakhkuda village in the extreme northeastern side, which cuts through a linear-spit that separates the lagoon from the main sea. The Zigzag outer channel connecting the lake and the sea is 25 km in length from Satpara village, which runs parallel to the coast and embodies a number of ephemeral sandy islands This channel has been branched into several creeks towards the lake It has no average width of 1 5km but at the mouth near Arakhakuda it is only 100m wide and 2 to 3 m deep Along the longest NE-SW

axis the main water body is 65 km and it has a maximum breadth of 1 5km. in the northern part.

2. Hydrological Zones: Hydrologically the lake consists of the Northern, Central Southern sectors and the outer channel There are many small and big islands in the lake of diverse origin "Nalabana" is an island of 35 sq km area which remains completely covered with marshy grasses and reeds. But most part of this island is submerged during rainy reason Few islands in the southwestern part of the lake like Kalijai and Ghantasila are inundated remnants of the main easternghats The remaining islands like Parikuda, Badakuda, Sanakuda, Titipo on the coastal side are made up of entrenched sand dunes. The lake receives fresh water from the river Daya, Bhargavi i e. the distributaries of the Mahanadi, Luni, Ratnachira and Kania of the northern side and a score of smaller streams and rivulets (i.e Malaguni, Dhanua, Salia etc) of the eastern slopes of the bordering Eastern Ghats from the Western side The addition of fresh water during rainy season by all these streams swells the lagoon into a fresh water ecosystem from July to December Otherwise from January to June, greater part of the lagoon remains as an estuarine ecosystem. Its physiographic, hydrographic and biotic features confirm to the characteristics of a typical coastal lagoon

3. Bathymetry of the Lagoon : The lake has an average depth of 1 35 metres the depth remains minimum in the summer months of April-June but reaches the highest level during the monsoon months of July-September when the lake surface rises to a level of 3.7 metres above mean sea level due to the heavy influx of fresh water from the catchments The maximum depth of the lake is in the southwest sector around Rambha and Kalijai area with a depth of 3.4 metres

4. Characteristics of Lagoon Evolution

The Chilika has a watershed area of about 4300 sq kms The northern part is a fertile alluvial tract of the Mahanadi delta The leached literite shelves and terraces occupy the northwestern part The western and southern part is boarded by denuded and dissected Easter-Ghats composed of Khondalites, gneisses, quartzites and unclassified granites The eastern part of the lake is a sand dune belt, which are mostly longitudinal and parallel The barrier spit, which separates the lagoon from the sea, is nearly 150m wide and 3 to 5 metres in elevation The formation of the lake has taken place due to the elongation of a spit from its southern extreme end at the palur hills where there is an abrupt curvature in the coastline Initially the bar

developed in a NNE direction under the impact of the long-shore drift ad the southerly waves. Farther north, the waves were probably building bars and barrier beaches that subsequently might have become the foundations of some of the present ridges and further building of the spit. Thus the extension of the spit from the southern end with the piling of the marine sediments by the waves, tides, long shore drift and the advancing delta front of the Mahanadi from the north cut off a portion of the Bay of Bengal and the Chilika was formed. The extension of the sand bar has not been a continuous process but has developed in successive stages through halting character With the passage of time the strong periodic monsoon cyclones developed in successive stages through a halting character With the passage of time the strong periodic monsoon cyclones developed complex hooks towards the lake and the major islands are the products of the periodic cyclones, which has a scouring effect on the low tide zone of the shoreline

5. Geomorphic Processes and Environmental Degradation of the Lagoon

The Chilika is basically an estuarine system with a tidal entrance to its northeast. Hence, the shore processes associated with the propagation of the waves, currents and tides are the potent forces of change, which affects its littoral environment and ecological degradation The natural changes which has taken place repeatedly in the past in the scaling and shifting of the lake mouth and narrowing of the outlets as response to the above mentioned natural processes is gradually preventing the inflow of saline water from the sea to the lagoon in maintaining a saline water from the sea to the lagoon in maintaining a stable saline environment.

5.1 Tidal Currents : The Chilika is exposed to the effects of the astronomical tides and the tidal currents which enter into it A twelve hour observation of the currents near the lake mouth during May (the peak season of in flow of seawater into the lake) and August (the peak season of outflow of fresh water from the lake to the sea) has revealed that the currents are semi diurnal In May, near the surface, the maximum tidal current speed was 18 3 cms./sec and maximum ebb current speed was 12 2 cms /sec Near the bottom the maximum peak and ebb current speed was 23 8 and 15 2 cms sec But during August the current at the lake mouth was directed continuously towards the sea during the entire tidal cycle with a speed of 57.3 to 45 cm/sec (Reddy, 1980) The inrush of the tidal current into the lake use to carry huge amount of sediments from the long shore drift and contribute in the process of sedimentation in the weed covered and mudflat zones, mostly in the summer season when there is no outflow of lake water into the sea.

5.2 Longshore Drift : Besides the tidal currents, the longshore drift has also been a pre-dominant agent along the Chilika coast which has affected the morphology of the lake and gradual shifting of its mouths When the waves approach a shoreline under the influence of the strong winds, the water level is slightly raised near shore by a slow shoreward drift of water. The excess of water being pushed shoreward, develop the longhsore current which move parallel to the shore in a direction away from the wind. Thus the longshore drift becomes the principal source of the supply of sediments to the lagoon besides the sediments of the feeding rivers

5.3 Wind and Waves : Along the Chilika coast the waves are the potential agents which carry enormous amount of sediments with it induced by the strong winds Very often the storm surges resulting from strong cyclonic winds causes large changes in the coastal zone, which often remain visible for decades. Along the eastern coast of Chilika, the winds are predominantly from the south and southwest in different months of the year. It can be observed that the bulk of the waves during the south-west monsoon and post monsoon season from June to November use to bring sedimentation in the lake, along the shore and lake mouth and consequently sets in the process of deterioration in the lagoon.

6. Shifting Lake Mouth and Deteriorating Saline Environment: A conspicuous feature observed in the deterioration of the saline environment of the Chilika seems to be due to the shifting of the lake mouth in a north easterly direction along with the reduction in its width ad the depth. This process prevents the tidal effect and reduces the free mixing of saline water with the lake water. The important facts considered for the instability of the lake mouth are the combined action of the waves, winds, tides and the long sore current The supply of sediments by the long shore current is apparently a more important factor because it brings suspended and bed material load into the tidal currents, which enter into the lake In the initial stage of the formation of the Chilika, the mouth was as wide as from the Palur hills to the Puri coast The process of further stretching of the bar seems to have been the root cause of the deteriorating environmental conditions in the lagoon and the whole process has initiated a change from a marine environment to brackish environment and in future it will be converted into a fresh water environment affecting the floral and faunal depletion

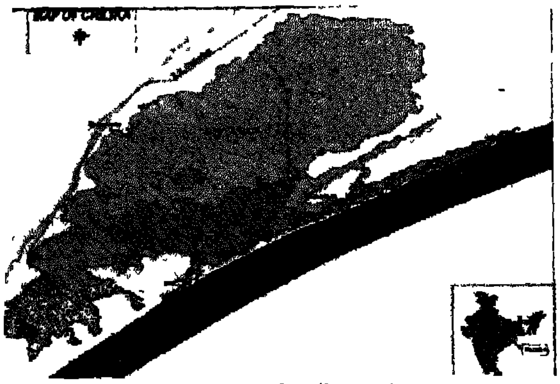
6.1 Catchment Degradation and Lagoon Siltation: Catchments degradation and sedimentation in Chilika has been a serious environmental problem. The river system that feeds

the lake supply enormous amount of silt and sediments (13m tonnes/year) making the lake shallow and turbid. The sedimentation in the lagoon is attributed to the rapid denudation in the catchments and removal of vegetal cover. As the mouth has already been shallow, the silt load from the lagoon is hardly pushed out into the sea The immediate siltation zone of the lagoon can be marked from the turbid zone of the Daya and Bhargabi mouth from the satellites imagery. In course of time the marshy areas has increased from 109 5sq kms. in 1975 to 21 sq kms. in 1987. Every year Chilika is shrinking by 1.45 sq kms. along the marginal zones

6.2 Population Pressure and Land Reclamation: Because of enormous economic potentiality of the Chilika about one lakh fisherman from 14 villages along its shore depend for their livelihood on it This pressure of population and human interference has also affected in the process of degradation of the lagoon environment Along the periphery, the lake is being reclaimed with the construction of ring embankments for the purpose of agriculture and prawn culture through small ponds.

7. Opening of New Mouth and Ecological Restoration

The continuing environmental degradation and the ecological deterioration of the lagoon eco-system has drawn the attention of the scientific community all over the world because of its international importance as a Ramsar Wetland Site The gradual chocking of the existing mouth due to siltation and poor mixing of saline water from the sea with the lagoon water has been considered as the most important natural factor for its environmental degradation In order to control influx of more saline water a new mouth was opened south of Arakhakuda at Sipakuda in the year 2002 After opening of new mouth there are indications in the ecological restoration of the lagoon It has increased the salinity of the lagoon water and consequently there has been a reduction in the fresh waterweeds from the lagoon and there has been an increase in the catch of fish and crabs from the lagoon



Out line map of Chilika Lake

Irrawady Dolphins of Chilika Lake at Satapada

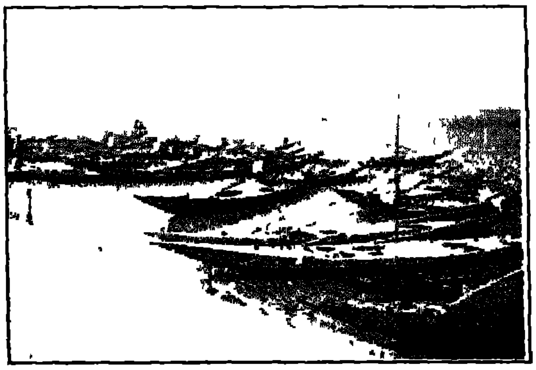
The New Mouth of Chilika Lake at Sipakuda

The Chilika Lake : Birds Paradise

Chilika Research Station & Ferry Craft at Satapada

Participants & Guide Teachers at Rajahansa Beach

Silting of the Lagoon in the Back Shore Zone



Traditional Fishing Boats at Satapada Jetty

8. Conclusion

In view of the rapidly deteriorating environmental conditions of the Chilika's wetland eco-system, the future strategy should aim towards environmental management of lake, its islands as well as of its surrounding catchments The estuarine character of the wetland should be protected with all its generic diversity with optimal salinity conditions through stabilization of the shifting and shrinking mouths· Dredging of the present mouth and opening of a few mouths to the southern section of the lake should be taken up to ensure the in-flow and outflow to and from the lakes. Removal of the aquatic weeds should be taken up and the silt carried into the lake should be checked by adequate soil conservation measures in its catchments Fishing should be restricted in its mouth zone and ecorestoration of the islands should be taken up to provide suitable habitat for the migratory and resident birds. Unless proper steps will be taken in these directions, the natural processes and human interventions will convert the lake into a marsh as it has already happened to the Samagara Pata and Sar Lake to the north of Puri town and will meet the same fate like Kolleru in the Godavari-Krishna deltas. Hence, monitoring of the geomorphic processes in and around the lagoon will not only help in preventing siltation in the lagoon but also will help in stabilizing the shifting lagoon mouths for maintaining a congenial saline environment with free exchange of Salinity between the lagoon and the sea which becomes the prime factor in the eco-restoration of the lagoon

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*** This Report is the compiled and edited version written by Dr. G. K. Panda from the study tour reports prepared by the participants.**

Observation Schedule
(Field Study at Satapada, Mahisamunda and Rajhansa in Chilika)

1. General Observations on Chilika

1.1	Dimension / Extension	a N-S (km) b. E-W (km) c. Shape d. Orientation to the Coast
1.2	Area of coverage	a. Summer Season b Rainy Season
1.3	Average Depth	a Southern section b Western section c Northern section d. Eastern section
1 4	Salinity	a North b Central c South
1.5	Outer Channel	a. Length b Depth (Average)
1.6	Mouths	a How many b Width c Depth
1 7	Weeds	a. Types b. Other vegetation species

2. Lacustrine Processes and Shore Processes

2 1	Tide – (on the day of visit)	a Tidal range b Time of High Tide c Time of Low Tide d. Colour of water during tidal ingression e. During Tidal recession f People's opinion on storm tides
2 2	Wind	**a. Direction** Morning Noon Afternoon b Velocity
2 3	Waves	a Amplitude (Ht) b Wave length c Breaker distance d Swash limit (outwards)

3. Materials of the Coastal / Lagoon System

3 1 Sediments in the lagoon zone
- a. Color
- b. Texture – Fine/ Coarse
- c Composition (grain size)
- d. Surrounding the island
- e Along the channel banks

3 2 Sediments of the Island
- a. Colour
- b. Texture – fine / coarse
- c Composition (grain size)
- d Surrounding the island
- e. Along the channel banks

3 3 Sediments of the spit / sand bar
- a Colour
- b. Texture – fine / coarse
- c. Composition (grain size)
- d. Surrounding the island

3.4 Sediments of the beach zone
- a. Colour
- b Texture – fine / coarse
- c. Composition (grain size)
- d. Surrounding the island

3.5 Sediments of the back shore zone
- a. Colour
- b. Texture – fine / Coarse
- c. Composition (grain size)
- d. Surrounding the island

4. Observation on the Landform

4.1	Spits (Rajhans)	a. Shape
		b Size length breath
		c Extension
		d. Materials
		e. Type of vegetation
4.2	Islands	a Shape
		b. Area
		c. Extension
		d Materials
		e Type Vegetation
4 3	Beach	a. Width
		b. Slope (gentle / steep)
		c Material composition
		d Extension
		e Beach Ridge
4.4		a. Shape
		b. Size
		c Extension
		d Material & composition
		e. Height (Relative)
		f. Type of vegetation

5. Nature of Flora and Fauna

5.1	Flora	a Types
		b Species
		1 Natural
		2 Exotic
		3 Aquatic
5 2	Fauna	a. Species
		b Terrestrial
		c. Aquatic
5 3	Avi Fauna	a Species
		b Indigenous
		c Migratory

6. Summary and Conclusion

6 1 Land form

6 2 Ecology

ORIENTATION OF GEOGRAPHY CONTENT ENRICHMENT FOR TEACHER EDUCATORS

TIME TABLE

DATE	9.00 AM – 10.30 AM	10.30AM – 12.00 NOON	12.00 – 1.30PM		2.30 PM – 4.00 PM	4.00 PM – 5.30PM
25.02.2004 Wednesday	Registration and Inauguration	Unit – 4 Dr. G.K. Panda	Unit – 9 Mr. P.K. Mohapatra	LUNCH BREAK 1.30 P.M. – 2.30 P.M.	Unit – 1 Dr. S.N. Tripathy	Unit – 13 Dr. P.K. Das
26.02.2004 Thursday	Unit – 5 Dr. G.K. Panda	Unit – 7 Dr. D. Tripathy	Unit – 10 Mr. P.K. Mohapatra		Unit – 2 Dr. S.N. Tripathy	Unit – 18(Pract) Dr. G.K. Panda
27.02.2004 Friday	Unit – 12 Mr. B.S. Mallasamanta	Unit – 8 Dr. D. Tripathy	Unit – 11 Mr. P.K. Mohapatra		Unit – 19 (Pract) Dr. S.N. Tripathy	Planning & Preparation for field study (Dr. G.K. Panda)
28.02.2004 Saturday	FIELD STUDY TO CHILKA				LAGOON	
29.02 2004 Sunday	Preparation of Field Study Report Dr. G.K. Panda	Preparation of Field Study Report Mr. P.K. Mohapatra	Unit – 16 Mr. N Dash		Unit – 3 Dr. S.N. Tripathy	Unit – 14 Mr. B.S. Mallasamanta
01.03 2004 Monday	Unit – 6 Dr. G.K. Panda	Unit – 15 Dr. P.K. Das	Unit – 20 Mr. P.K Mohapatra		Unit – 17 Mr N. Dash	Veledictory Function